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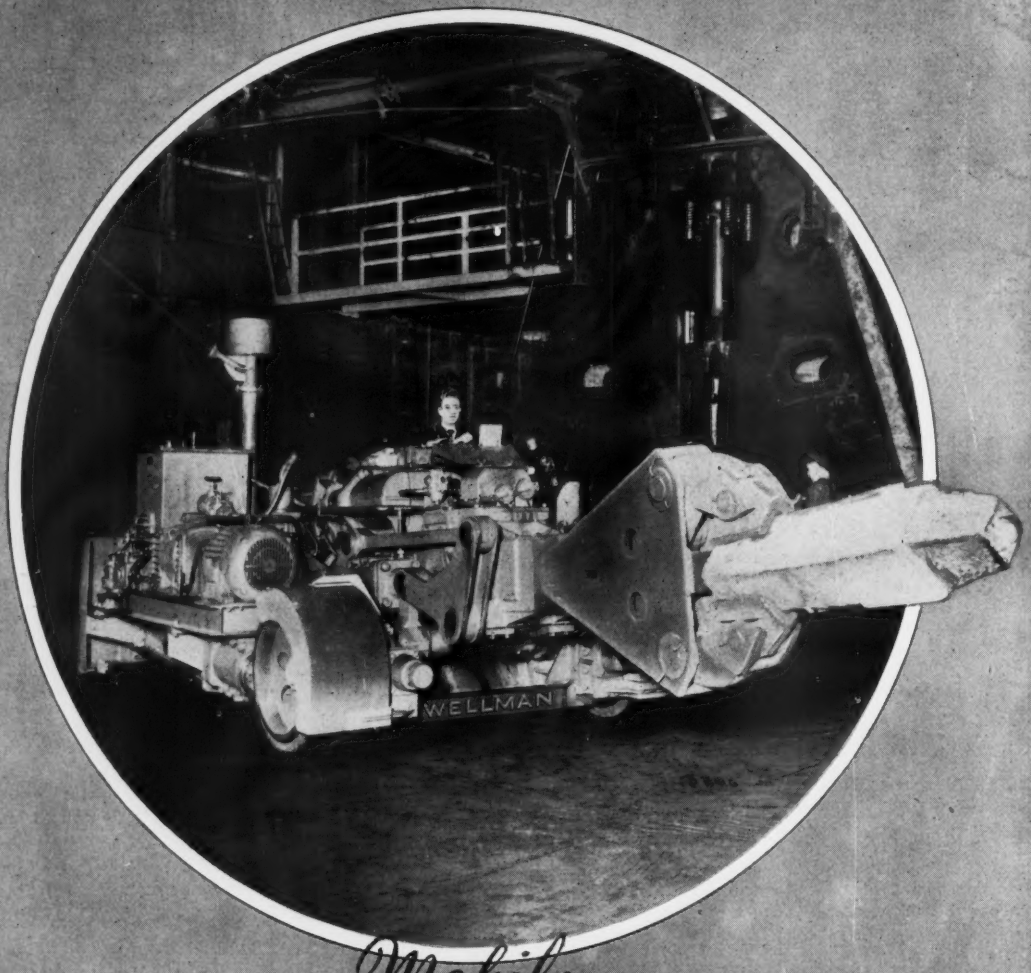

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ARTHUR DORMAN, J.P.

MR. ARTHUR DORMAN was born at Norton-on-Tees in 1881, the youngest son of the late Sir Arthur John Dorman, Bt., K.B.E., joint founder of the company which bears his name. He was educated at Rugby School and Cambridge University, where he obtained the degree of M.A. He started his business career with Dorman, Long and Co., Ltd. in 1903, and was elected a Director in 1908. In the first Great War Mr. Dorman served in the 4th Battalion of the Yorkshire Regiment, and was mentioned in despatches. In 1923 he was appointed Managing Director of Dorman, Long and Co., Ltd., and acted in this capacity for seven years. In 1931 he was appointed Vice-Chairman and then, in 1934, Commercial Director. In January of last year he relinquished the latter appointment and became a non-executive Director.

Mr. Dorman has also been interested for many years in a number of other companies. In 1929 he became a Director of Bowesfield Steel Co., Ltd., and Redpath Brown and Co., Ltd., and Chairman of British Structural Steel Co., Ltd. In following years he was elected a Director of Tees Side Bridge and Engineering Works, Ltd. ; Horden Collieries, Ltd. ; Dorman Long (Africa) Ltd. ; Darlington and Simpson Rolling Mills, Ltd. ; Associated British Manufacturers (Egypt) Ltd., among other companies, including the overseas subsidiaries of Dorman, Long and Co., Ltd. He is Chairman of Pearson and Dorman Long, Ltd., and Vice-Chairman of British Iron and Steel Corporation, Ltd.

Local affairs, industrial and technical, have made great demands on Mr. Dorman's time. He is a Past-Chairman of the Cleveland Ironmasters' Association, and was Chairman of the Cleveland Mine Owners' Association until 1st February, 1949. He was President of the Tees Side Chamber of Commerce from 1937 to 1938, and Chairman of the National Council of Iron Ore Producers for the year 1947.

Mr. Dorman is a Past-President, Vice-President and Member of Council of the Cleveland Institution of Engineers and acts as Donor's representative on the Council of the Cleveland Scientific and Technical Institute. He is a Justice of the Peace for the North Riding of Yorkshire and an officer of the Order of St. John of Jerusalem.

Among other activities of a national character, Mr. Dorman was President of the National Federation of Iron and Steel Manufacturers (now the British Iron and Steel Federation), from 1923 to 1924, and for a number of years was a member of its Executive Committee. He is also a Past-President of the National Confederation of Employers' Organizations, now the British Employers' Confederation, and a Vice-President of the Federation of British Industries. Mr. Dorman had been actively concerned with the affairs of many trade associations ; he was Chairman of the Rail Makers' Association and recently received a presentation when, after many years of service, he relinquished the Chairmanship. He is also a Vice-President of the Institute of Welding. He became a Member of The Iron and Steel Institute in 1908, was elected Vice-President in 1932, and served as President from 1944 to 1946.

Arthur Dorman, J.P.
President 1944-1946

IRON AND STEEL
INSTITUTE PAPERS

PLANT DESIGN · MANUFACTURE · RESEARCH · DEVELOPMENT

The Preparation of Thin Steel Specimens by Cutting

AND THE ISOLATION OF NON-METALLIC INCLUSIONS *IN SITU* BY A SIMPLIFIED CHEMICAL METHOD

By Carl Benedicks and Olof Tenow

SYNOPSIS

A method of preparing, by means of a microtome, thin steel specimens down to 20μ in thickness, is described, together with details of the development of the method. The thin specimens, so prepared, have been used for the isolation *in situ* of non-metallic inclusions in steel by means of a new chemical method.

An important result of the investigations is the abundant occurrence, in AlN-rich steel, of thin, adsorbed films, which are visible on account of their absorption of light.

One of the most important problems of modern metallography of steel is the study of the adsorption of certain substances in the grain boundaries where they may exert an influence in inhibiting grain growth.[1–5] Such an influence by the nitride AlN has been established by Kjerrman.[6]

A method has been devised by Skapski and Benedicks[7] for examining *in situ* the occurrence of non-metallic particles, by means of gas reactions (chlorine and hydrogen chloride) at temperatures of 600° to 850° C.

The use of a single polished surface for the microscopic examination of steel, as introduced by Sorby, has caused the preparation of thin specimens—also used by Sorby for the examination of transparent minerals and rocks—to be neglected. Thin specimens, as used in biological research, yield much more than does a single surface, if the subject is transparent. The removal, by chemical means, of the bulk of the metal may be regarded as being equivalent to making the specimen transparent, and thus enables the particles not dissolved to be observed *in situ*.

PREPARATION OF THE SPECIMENS

The specimens must be very thin, say, 0·02 mm. for a fine-grained steel of grain-size 8–9 (Jernkontoret JKM), and of uniform thickness. Suitable specimens cannot be obtained by rolling, as the existing structure is altered in the process. Grinding can be used, but there is the possibility that some grinding powder may be embedded in the structure. Grinding has been used with some success by Betteridge and Sharpe[8] for producing thin samples (0·025–0·050 mm.) for X-ray micro-radiography. In their case a magnification of $\times 150$ would rarely be exceeded, however, whereas in the present case magnifications of $\times 1500$ can be used with advantage. The only rational way of preparing thin steel specimens for the present purpose is therefore by a cutting process.

PRELIMINARY INVESTIGATIONS

Milling Tests

The first attempts at producing good plane surfaces by cutting were made on a Swiss precision bench milling machine (Christen, Bern, type *F*12), with cylindrical plain milling cutters. In spite of good axis bearing, the surfaces obtained were not plane enough, owing to unavoidable variations in the rotation of the axis, and to the slight eccentricity of the cutter which could not be entirely eliminated.

A solidly built microtome* was tried next. Such instruments have been used for cutting plain surfaces on wood and soft metals.[9] As the knives supplied with the microtome were unsuitable for harder materials, the next problem was to decide on the best form, material, and application of the cutting

Manuscript received 30th August, 1948.

Professor Benedicks and Mr. Tenow are engaged in research at the Laboratorium C. Benedicks, Stockholm.

* Hljung, Heidelberg, type *K*.

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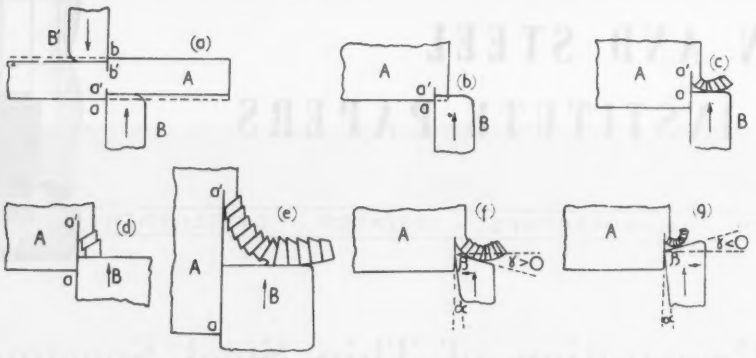


Fig. 1—Chip formation in steel cutting

tool. First, it was considered essential to have a clear idea of the processes taking place when a metal is cut.

The Fundamental Process in Steel Cutting

In spite of the great amount of work that has been published on the cutting process,[10–13] the theories given were not considered satisfactory for the purpose, and the following was evolved in conjunction with a previous analysis by Benedicks.[14]

In Fig. 1*a*, *A* represents a piece of metal sheet, and *B*, *B'* are a pair of shearing jaws placed at a certain distance from the end of *A*. When stressed as shown by the arrows, shearing cracks *aa' bb'* will develop from *B*, *B'* respectively, towards the centre, resulting in fracture of *A* into two pieces. If *A* is thick enough, one shearing crack only need be considered.

Suppose that the sharp corner of *B* acts upon *A* very near its end, as in Fig. 1*b*. From the foregoing, a shearing crack *aa'* will be caused. No movement of the material being possible to the left of *aa'*, that to the right will be deviated to the right, owing to the pressure exerted by the surface *B*, as in Fig. 1*c*.*

The deviated layer, which will be subjected to certain internal slip, will form a curved chip. As no satisfactory exposition of the formation of a steel chip could be found in the literature, the following tentative explanation may be of interest.

As already pointed out, the metal to the right of *aa'* is subjected to a compression ; this will cause a tendency towards shear deformation, which is shown schematically in Fig. 1*d*. (The other symmetrical shearing plane forming (theoretically) similarly at 45° to the stress, will not come into play owing to the presence of *A*.) The movement of the chip to the right will appear as in Fig. 1*e*, with the characteristic stepped inner surface. The outer surface will be smoothed-out by contact with the tool *B* (causing a local wearing of *B* at the point of contact). It is assumed in this explanation that shearing planes are formed in the chip. With soft metals the shearing steps will be very small—as also will the free space below the chip on the left of the contact point *B*, where metal dust frequently forms an agglomeration.

* This process of cutting is used in the present experiments ; with a soft, plastic metal, particularly when using a high speed and feed, the chip formation may take place in another way (as is frequently assumed).

The most important part in the formation of chips in metal cutting is the occurrence of a shearing fissure *aa'* which occurs when the working surface of *B* is perpendicular to its displacement (Fig. 1*c*). The primary condition for the formation of a curved chip is that the sharp edge of *B* shall be applied near the free surface of *A*, giving rise to a shearing fissure.

The bending of the chip must depend, besides on the thickness of the chip, on the slope of the front surface of the tool, *i.e.*, on the lip angle β (Fig. 1*f*). It is most usual for the lip angle to be less than 90°, as in Fig. 1*f*, and with a small working relief angle α, in order to give a good point contact at the very edge of the tool. In this case, with, say, $\beta = 70°$ and $\alpha = 5°$, the bending of the chip is not so drastic as when $\beta = 90°$ (*cf.* Fig. 1*c*), and when the rake angle γ ($= 90° - (\alpha + \beta)$) is positive. Alternatively, the angle $(\alpha + \beta)$ may be greater than 90°—when the rake angle will be negative (Fig. 1*g*). This arrangement is in common use as the cutting edge is less likely to be damaged than with a positive rake angle.

Obviously, with a negative rake angle the chip is bent more sharply and must be kept thinner than when the rake angle is positive. A negative rake angle may be capable of giving a very smooth surface, but it demands a high speed and can be used only with tools of the very hardest materials.

If $\gamma = 0$, the shearing fissure must be parallel with the free surface (as shown by *aa'* in Fig. 1*c*), but if γ differs from zero it is possible that the fissure will form some angle with the free surface (which would make Figs. 1*f* and 1*g* slightly incorrect). If the working direction of the tool is parallel with the free surface the shearing fissure will have a zigzag shape, and the cut will not give the best plane surface.

The conclusion to be drawn from this analysis is that, for the present purpose, the tool should have a rake angle (γ) of zero and a small relief angle (α), thus avoiding the formation of zigzag planes and giving the smoothest possible surface. In addition, the cutting edge will be protected against damage, and the feed (or chip thickness) must be small, as is also demanded by the microtome work to be carried out.

A further advantage is derived from a tool of this shape. Referring to Fig. 1*f*, where γ is positive, a momentary local increase in the resistance against

the tool may cause a sideways deviation towards A, as shown by the smaller arrow, and, from Fig. 1*g*, a deviation from A will occur when γ is negative. Hence the smallest tendency to deviation from a smooth plane will be when the cutting surface is at right-angles to the work surface. In this case only will varying resistance cause no lateral motion of the tool. Now, from Fig. 1*c*, which illustrates this arrangement, the running-off chip may cause a slight deviation of the tool to the right. Therefore the ideal arrangement is to use a very small positive rake angle.

The foregoing analysis served as a guide to the procedure to be adopted in the experiments.

Neutralization of Elastic Deformation

It was assumed in the previous section that the cutting edge was moving strictly in the same plane. Experiments showed, however, that a certain undesirable lateral displacement of the edge did occur. This problem was examined as follows :

Suppose that the cutting tool A is in itself perfectly rigid and cannot be deformed, and that it possesses an elastic mobility around a centre, B (Fig. 2*a*). The tool may be supposed to be kept in position by two strong springs C, C'. If the resistance against motion is constant, A occupies a fixed position. If, now, the cutting edge encounters a locally increased resistance, it will move a certain distance along a circle with centre B, as shown by the broken line in Fig. 2*a*, the edge penetrating deeper into the material, *i.e.*, deviating from the working plane. If, on the contrary, the elastic centre B is placed before the edge, as in Fig. 2*b*, an increased resistance will cause a less deep penetration.

The case shown in Fig. 2*a* is the most common in metal cutting (with a straight holder). It involves

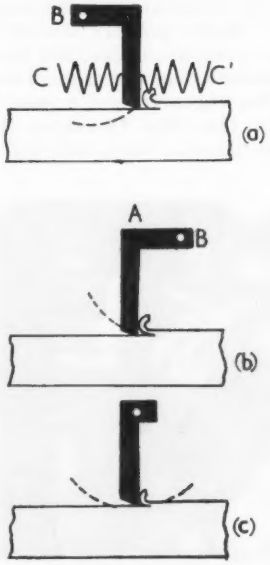
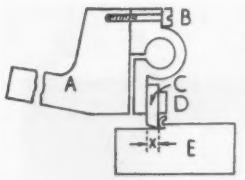
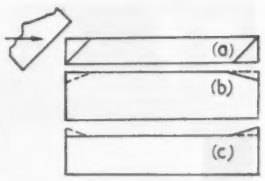


Fig. 2—Influence of the elastic (bending) centre of the tool



(Fig. 3)



(Fig. 4)

Fig. 3—Diagram of the tool holder

Fig. 4—Formation of facets, as determined by the position of the elastic centre, (*a*) plan view, (*b*) and (*c*) side elevations

the practical disadvantage that, on increased resistance, the edge cuts deeper and causes a higher power consumption. Figure 2*b* gives the practical advantage that, on increased resistance, the power required diminishes, on account of the raising of the edge. This arrangement has long been used by forging the cutting tool to a **U**-shape at the edge ("gooseneck finishing tool"), the elastic centre B being before the edge.

For the present purpose both cases are unsuitable, the first giving rise to furrows in the work and the second to ridges. To produce a really plane surface the elastic centre of the tool must be situated on the normal of the worked surface, passing through the cutting point (Fig. 2*c*). If this cannot be realized exactly, an approach to Fig. 2*b* is better than an approach to Fig. 2*a*, since ridges are generally less inconvenient than furrows.

In order to localize the unavoidable elastic deformation an arrangement as shown in Fig. 3 was used. On to the tool holder A (made as stable as possible) is welded a solid heel, with a well-planed vertical surface. On to this is bolted the part B carrying the tool C held in a screwed jaw D. To localize the elastic deformation when cutting the material E, B contains a slotted boring, machined round the outside to the shape shown in Fig. 3. The centre of the boring is 1·2 mm. to the right of the plane supporting the tool C, and coincides nearly with the elastic centre. The cutting edge of the tool is arranged as in Fig. 2*c*.

It is difficult to find exactly the elastic centre. With tools of slightly different thickness x, an uneven surface was obtained, consisting of ridges when $x = 0{\cdot}9$ mm., and of furrows when $x = 3{\cdot}0$ mm. Only with a tool of thickness $x = 2{\cdot}6$ mm., was the surface produced practically free from such unevenness. Hence the exact position of the cutting edge in relation to the elastic centre is extremely important. The elastic centre was thus $2{\cdot}6 - 1{\cdot}2 = 1{\cdot}4$ mm. to the right of the centre of the boring.

The best position of the cutting edge was determined as follows : Suppose the cutting edge to approach at 45° a rectangular piece of work, as seen in plan in Fig. 4*a*. When the edge encounters the nearest (top left-hand) corner, it occupies a definite level, corresponding to the absence of stress. The stress then increases linearly with the displacement, until the chip has increased to its full width (in the next moment the edge reaches the bottom left-hand corner of the work). Now, provided that the increasing stress causes the edge to rise (as in Fig. 2*b*), an

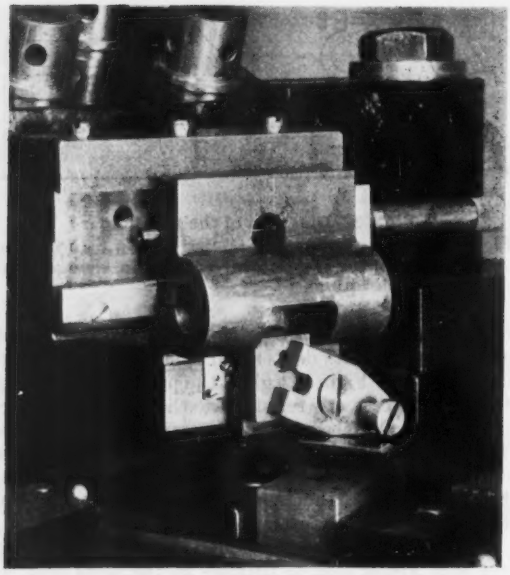


Fig. 5—Tool holder in use

upward-sloping plane will be formed, which is then transformed into a horizontal plane (Fig. 4*b*, side elevation). A corresponding downward slope will be formed at the other end of the work piece. By determining the angle between these sloping planes and the horizontal, a measure is obtained of the incorrectness of the position of the edge. If an increased stress causes a lowering of the edge (as in Fig. 2*a*), the result will be the reverse, as in Fig. 4*c*.

A sensitive height-measuring device, such as a micro-cator (C. E. Johansson) may be used instead of angle measurement if desired.

The high-speed-steel tool showed considerable local wear, no doubt because of non-metallic inclusions in the specimens. Welding-on of iron traces was also noticed. Hard-metal (tungsten carbide) was therefore used, and besides having a great resistance to wear, welding-on did not occur. The brittleness of hard-metal was counteracted by using a cutting angle of 90° or slightly more.

Since a perfectly smooth surface could not be expected with a sintered material, the tool holder used had a sideways displacement (Fig. 5), by means of which a suitable portion of the edge could be selected.

PRELIMINARY MACHINING

Sawing

The first operation is the preparation, by sawing, of a blank. The piece to be sawed (25 × 20 × 8 mm.) was firmly gripped along the whole end surface in a vice. The vice was mounted on a vertical slide, fixed on the cross slide of a gear-cutting lathe. The sawing was done successively, with the aid of the automatic cross feed. The thickness of the slice was 0·5–1·0 mm. If not gripped in this way the slice will not be uniform.

Milling

To save time in the subsequent microtome work, the blanks were next milled to a convenient thickness, say, 0·08 mm. A castor-oil colloid was used as cutting fluid, and had the following composition: Green soft soap 34, castor-oil 34, turpentine 10, and water 22 parts by weight.

USE OF THE MICROTOME

Preparing the Cutting Edges

The hard-metal Seco *G*1 (Fagersta) was selected as the material for the cutting edges, as this was considered to be comparatively tough. The pieces were 16 × 10 × 5 mm., the 16 × 5-mm. surface making an angle of 78° with the 16 × 10-mm. surface; this latter surface was ground and polished (using the finest diamond powder on an iron plate). The edge angle (78°) was, on a small face, altered to 82°, and the relief angle was 6°.

The polishing of hard-metal surfaces free from scratches is by no means a simple task. An edge polished by a skilled polisher showed faults up to 26μ from the geometrical edge, but by careful work it was possible to reduce the primary faults to below about 1μ. The appearance of a good fresh edge is shown in Fig. 11*a*; Fig. 11*b* shows the edge after finishing a 0·02-mm. sheet, and Fig. 11*c* after a

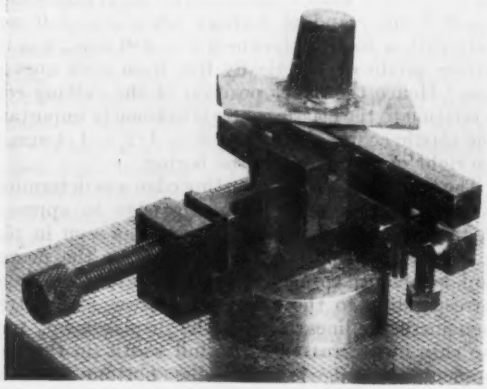


Fig. 6—Apparatus for sharpening hard-metal edges

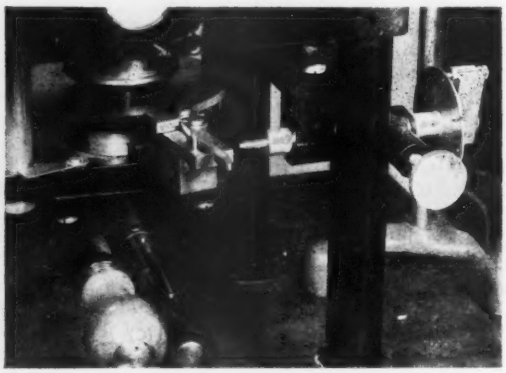


Fig. 7—Micrometer screw for feed regulation, with dividing disc

somewhat prolonged use, indicating that the Seco edge requires frequent sharpening.

For sharpening, a small plane iron sheet, 3 mm. thick was used, with fine diamond powder. When grinding, the plate rested, besides on the edge itself, on the rear border of the tool holder, which is parallel to the edge (*see* Fig. 5); the iron sheet, fixed to a cork which acts as a handle, can be seen in Fig. 6. Frequently a more effective sharpening is desirable and for this purpose a special grinding fixture was made (Fig. 6). By means of a precision ledge and knob, the tool could be replaced exactly in its original position.

Sliding Motions

Owing to the large sliding surfaces, the horizontal sliding motion of the microtome was found to be very accurate (when checked with a micro-cator—1 division equals 0·2μ), but the vertical sliding caused much trouble. It consisted of a brass cylinder, moving with considerable play, which introduced two faults :

(1) A lack of definition of the angle between the axis and the vertical line ('angular play'). This was effectively counteracted by a horizontal steel rod, fixed by a small clamp on the vice holding the specimen, and causing, by means of a weight, a constant angular momentum (33·6 kg. cm.). This rod, gliding against a felt pad, also provided damping (*see* right-hand side of Fig. 10).

(2) A considerable end float. In spite of good stability against pressure exerted from above, in a particular case, when the tool edge was very sharp, this end float caused a 0·10-mm. thick specimen to be cut through. It was found that pressure from below could raise the specimen as much as 0·090 mm. By tightening the corresponding nut as much as possible there was still a 0·050-mm. float.

To perfect the micro-cutting process, an improved construction of the vertical slide will be necessary.

The Microtome Feed

The minimum feed of the microtome was originally 2μ. As this was too coarse for the present work the existing stop rod was substituted by a 1-mm. micrometer screw, provided with a 4 or 6 dividing disc, with an index (Fig. 7). This arrangement gave a feeding down to $\frac{1}{6}\mu$, and worked for a length of 25μ, after which the micrometer screw had to be turned back, working on another part of the ratchet wheel.

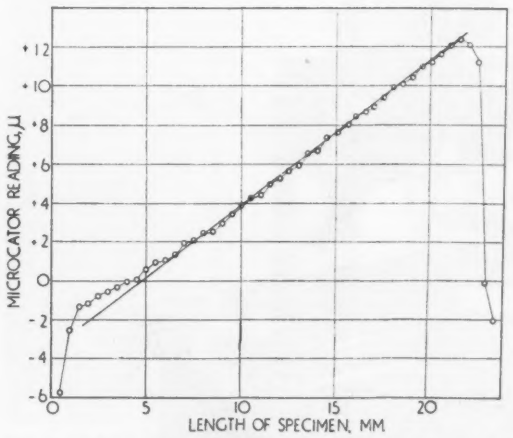


Fig. 8—Micro-cator diagram (motor driven, vertical slide stabilized)

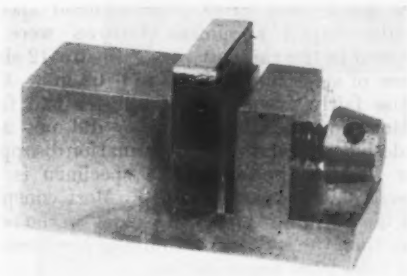


Fig. 9—Brass vice for holding the blocks transversally

Working Speed

The original motor speed was much too high, and was therefore reduced 7·5 times by an interposed transmission, giving a rotational speed of the main axis of 15 r.p.m. Even then, however, the speed, which corresponded to a cutting speed of 9 mm./sec., was too great for final cutting. An additional electrical resistance was introduced into the motor circuit so as to lower the speed during the cutting period only. In this way the cutting speed was reduced to 6·1 mm./sec., without greatly increasing the total working time.

The surface quality obtained is indicated in Fig. 8; irregularities are fairly small, about 0·2μ, and a large part of the surface is plane.

Adjustments to the Microtome Vice

The vice of the microtome was found to lack the necessary precision. The jaws had to be fine-ground on two faces, and the groove for the tightening screw had to be carefully centred. A transversal vice, made in brass (Fig. 9), was attached to the microtome vice to keep the specimen or its supporting block in a reproducible position. For accurate and solid location of the block, two pyramidal warts on the lower part were pressed in the microtome vice between two copper plates (Fig. 9).

Soldering the Specimens

Common solder (lead 50, tin 50), although not ideal, was used to fix the specimen to the supporting block. Cements were found to be unsatisfactory. The soldering was carried out in the following way : The supporting block (previously made parallel in the microtome) and the specimen were carefully tinned on one side with a soldering bit ; the surplus solder was removed so as to leave thin, even coatings, and both surfaces were varnished with a solution of colophony in etanol, and then firmly pressed together in a toolmaker's vice, a small piece of blotting paper being placed directly on the thin specimen, which was then heated up to 210° C. in a small electric oven. At this temperature the surplus of the solder is slowly pressed out; in the few cases measured, the remaining layer was found to be about 1μ thick.

A better surface was generally obtained on a

massive block than on a thin soldered specimen. On wedge-shaped specimens furrows were most pronounced in the thinnest part. Figure 12 shows a specimen of steel *B*, cut down to 0·02 mm. On the otherwise fairly even surface a blister had formed, indicating that, locally, the solder did not adhere. When desoldering, the blister deformation disappeared. Similar blisters appear when a specimen is milled to a small thickness (*see* Fig. 13). Most conspicuous are the discontinuities from the solder on the borders, proving that the strain from milling has been much greater than from micro-cutting.

Cutting Fluid

A cutting fluid is essential for good work ; besides its lubricating quality, it must possess a high wettability,[15] to facilitate the formation of chips. The wettability of the fluid decreases on standing (for several weeks). The composition of the cutting fluid was the same as that used for milling the blanks (*see* p. 180).

The fluid must be used in large quantities to make use of a third desirable influence : that of damping vibrations. Figure 14 shows a case of insufficient damping. For some reason, perhaps hard inclusions, vibrations have set in, causing the appearance of a periodicity (or grating). Figure 15, the same specimen, gives evidence that the period here is the first octave of the previous one. On visual inspection, these parts exhibit a beautifully coloured grating effect.

To counteract vibration, the viscosity of the fluid should be high, but if too high, the wettability will be low, necessitating an extremely low cutting speed. Hence a compromise should be made when deciding on the viscosity.

Control of Thickness on Cutting

The procedure of cutting will now be described. The moving part in this description is the specimen *E* in Fig. 3. Cutting begins when the specimen returns from its extreme position on the right-hand side of the tool.

(1) The thickness of the milled blank on its slightly projecting supporting block is measured in a microscope in vertical illumination, at both ends. For a given case the figures obtained were 37·2 and 37·6μ, average 37·4μ. The final desired thickness being 20μ, it was necessary to remove 17·4μ.

(2) The specimen is raised so as to approach the cutting edge by turning the crank of the microtome anti-clockwise until hardly any light can be seen between the edge and the specimen.

(3) The feed-disc index is set in the correct initial position in the following way : The carriage, with the specimen, is moved to its extreme right-hand position. The ratchet arm is turned to the right until contact is made with the micrometer screw (*see* p. 181), the index of which is set at zero. The carriage is then moved to the left to perform the first cutting stroke. A few preliminary strokes are made until a regular cutting sets in ; and the instrument is then ready for work.

(4) The first few feeds may be taken at about 1μ. After the first stroke of the specimen in a left-hand direction, the specimen is lowered, so as to avoid unnecessary wear of the edge, by turning the feed crank clockwise to an existing stop.

(5) A fresh appropriate setting of the feed index is made. The specimen, after being returned to its position on the right of the tool, is subjected to a thick layer of the cutting fluid. Subsequently, the feeding arrangement is brought into action automatically (thereby the previous lowering of the specimen does not exert any influence). This completes the cycle of operations.

The following figures are a record from an actual cutting process. It should be noted that it is necessary

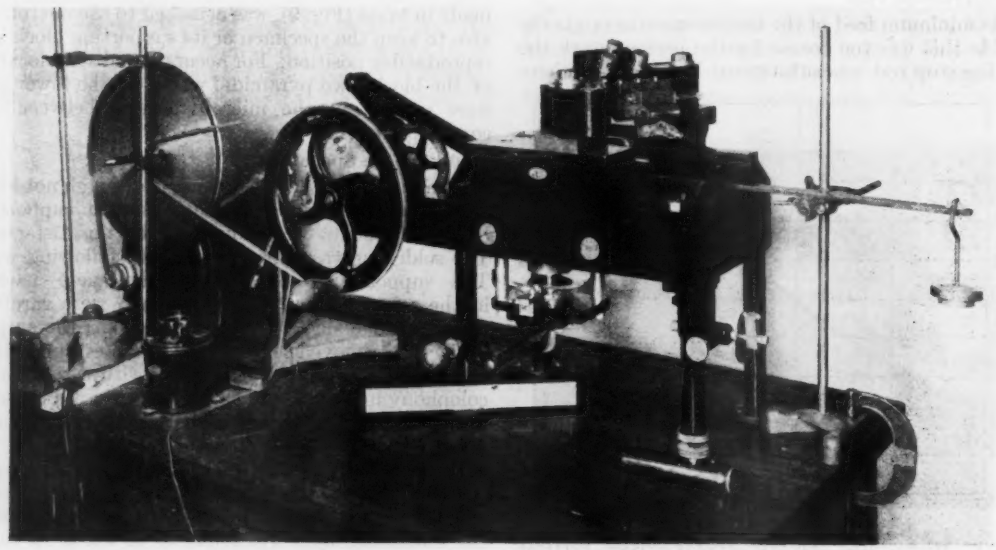


Fig. 10—Complete micro-cutting apparatus

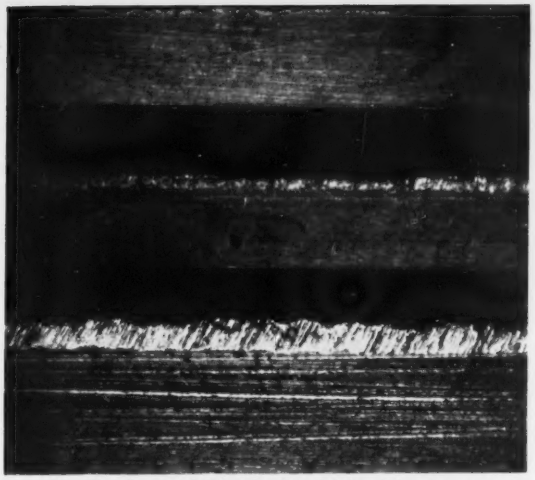


Fig. 11—Hard-metal (Seco) edge (*a*) freshly sharpened, (*b*) as used for finishing a 20-μ specimen of steel *C*, and (*c*) after prolonged use × 220

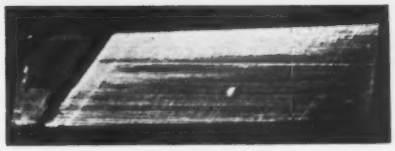


Fig. 12—Specimen of steel B, cut down to 0·02 mm., showing formation of blister in the solder × 2·5

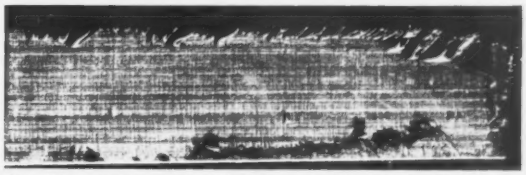


Fig. 13—Appearance of blisters and irregularities after milling (steel B) × 2·8

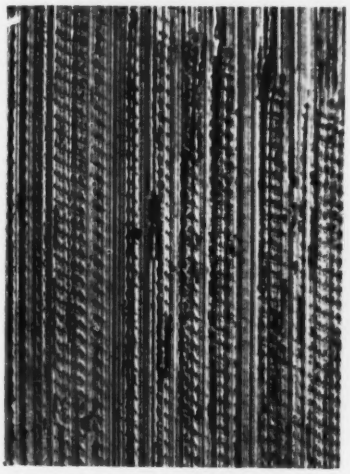


Fig. 14—Steel B. Grating formed during micro-cutting through insufficient damping by cutting fluid × 500

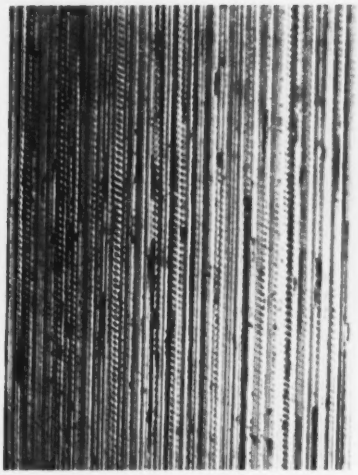


Fig. 15—As Fig. 14, but showing the period to be the first octave of that shown in Fig. 14 × 500

Fig. 16—Milled surface of a specimen of steel *B* × 50

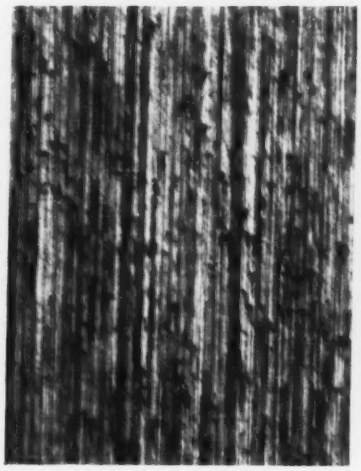


Fig. 17—Micro-cut surface of a specimen of steel *B* × 50

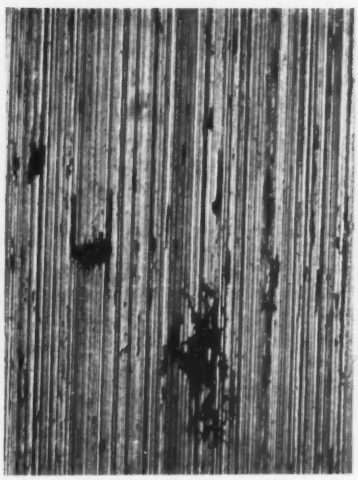


Fig. 18—Same specimen as Fig. 17, showing slag inclusions × 110

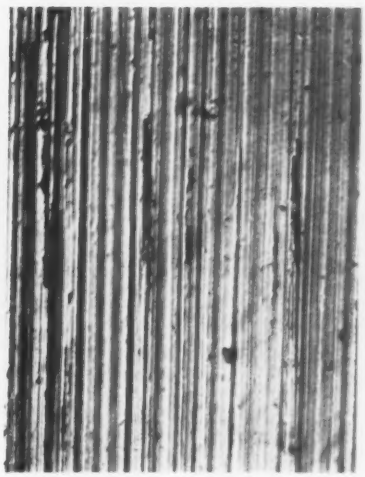


Fig. 19—Micro-cut surface of the AlN-rich steel C, showing a number of hard inclusions × 500

[*Benedicks and Tenow*

[*To face p.* 182

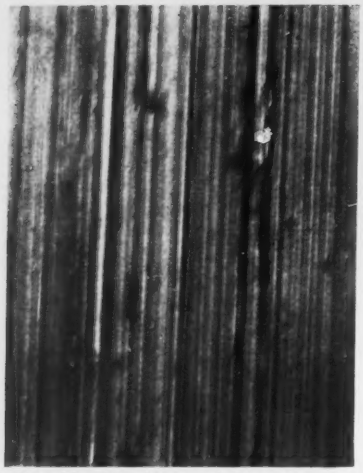


Fig. 20—Specimen of steel B cut down to 0·013 mm. at right-angles to the direction of rolling × 500

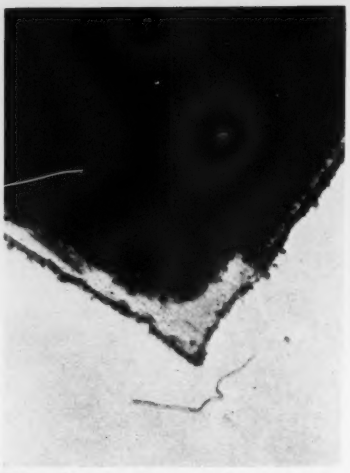


Fig. 21—Specimen of steel A partly dissolved in 0·5% bromine-metanol, the coherent residue being visible at the borders × 45

Fig. 22—Steel A, dissolved in 8% bromine-etanol. A considerable part of the residue is folded × 45

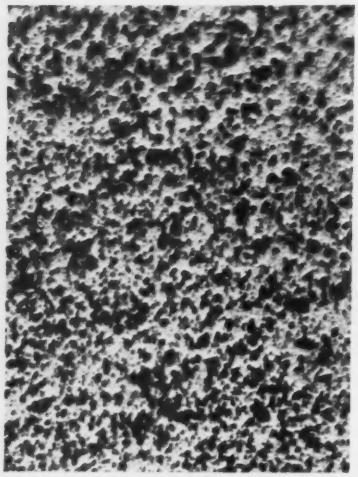


Fig. 23—An undamaged part of the residue shown in Fig. 22, containing (Fe, Mn)-spinel and probably (Fe, Mn)O × 600

Fig. 24—Specimen of steel B (5% bromine-etanol), showing the highly coherent residue × 90

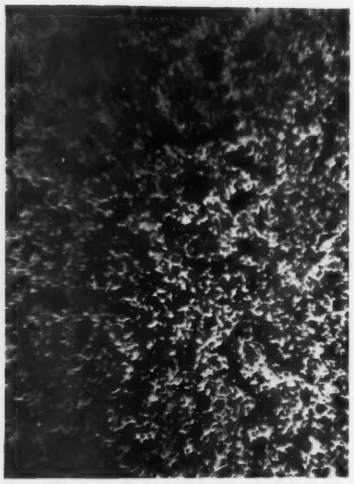


Fig. 25—As Fig. 24, but at higher magnification, showing a large amount of inclusions × 230

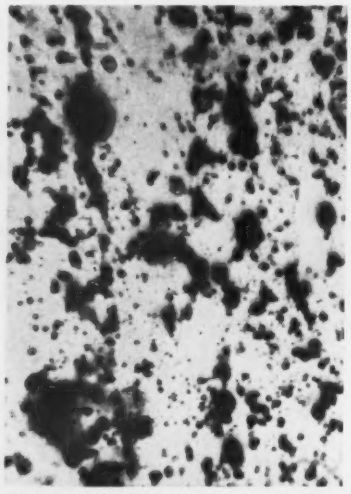


Fig. 26—As Fig. 25, but at higher magnification, and taken with damping rod in position × 1250

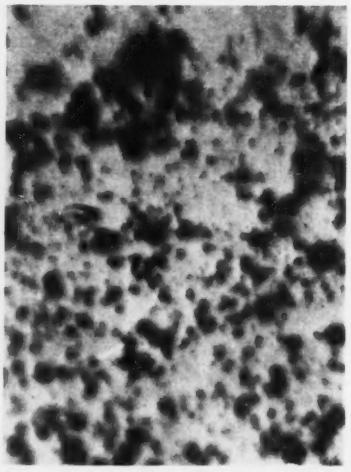


Fig. 27—As Fig. 26, but taken without the damping rod × 1250

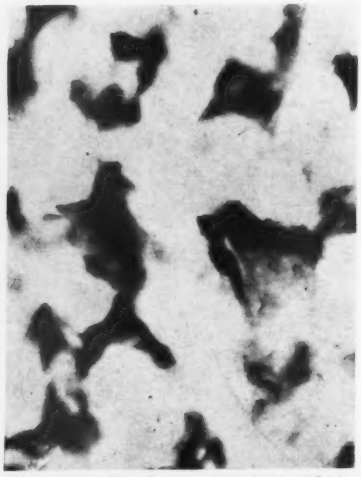


Fig. 28—Steel C, reagent 10% bromine-etanol. The thin dark films, mostly rolled-up irregularly, probably correspond to adsorbed AlN occurring in the grain boundaries × 1250

to diminish successively the amount of feed (*cf.* wire drawing) :

Feed Settings Made before Successive Cuttings, μ

1–4	$10\frac{3}{8}$	13	$15\frac{3}{8}$
5	$10\frac{1}{4}$	$13\frac{1}{8}$	$15\frac{1}{4}$
6	$10\frac{5}{8}$	$13\frac{3}{8}$	$15\frac{5}{8}$
7	11	$13\frac{3}{8}$	16
7·5	$11\frac{1}{8}$	$13\frac{1}{4}$	$16\frac{1}{8}$
8	$11\frac{3}{8}$	$13\frac{3}{8}$	$16\frac{3}{8}$
8·3	$11\frac{3}{8}$	14	$16\frac{3}{8}$
8·6	$11\frac{1}{4}$	$14\frac{1}{8}$	$16\frac{1}{8}$
9	$11\frac{5}{8}$	$14\frac{3}{8}$	$16\frac{5}{8}$
9·3	12	$14\frac{3}{8}$	17
9·6	$12\frac{1}{8}$	$14\frac{5}{8}$	$17\frac{1}{8}$
9·8	$12\frac{3}{8}$	$14\frac{5}{8}$	$17\frac{3}{8}$
10	$12\frac{3}{8}$	15	$17\frac{3}{8}$
$10\frac{1}{8}$	$12\frac{1}{4}$	$15\frac{1}{8}$	$17\frac{1}{8}$
$10\frac{3}{8}$	$12\frac{5}{8}$	$15\frac{3}{8}$	Burst

It will be seen that the intended figure, 17·4μ, was slightly exceeded, with the result that the sample burst.

The complete micro-cutting apparatus is shown in Fig. 10.

Surfaces Produced

The character of the steel surfaces produced by cutting has already been described geometrically (*see* page 181 and Fig. 8). In Figs. 16 and 17 are shown a milled surface and a micro-cut surface, respectively, of steel *B*). The milled surface appears at first to be quite good, but seen with the naked eye it has a grey appearance, owing to its roughness. The micro-cut surface is much brighter, and the inclusions are more easily seen under the microscope than in the case of the milled surface, as would be expected. If a one-sided ultropaque illumination is used, the shallow scratches almost entirely disappear and hence the surfaces are suitable for microscopic examination. For studying the surface character, vertical illumination was found to be more suitable.

The same specimen is shown again in Fig. 18. The irregularities are slag inclusions and are not due to the cutting. Figure 19 shows the surface of the AlN-rich steel *C*. A considerable number of hard inclusions are visible.

The cutting direction for the specimens shown in the foregoing photographs (Figs. 14 to 19) was parallel to the direction of rolling. This is to be recommended as the risk of bursting is then smaller than when cutting at right-angles to the rolling direction. It is not, however, essential, as is indicated by Fig. 20, which shows a small specimen of steel *B* cut down to the exceptionally small thickness of 13μ at right-angles to the direction of rolling.

CHEMICAL ISOLATION OF NON-METALLIC INCLUSIONS

Included in the programme of the present investigation was the development of methods of examining non-metallic inclusions in the thin steel specimens produced.

In the pioneer work of Skapski and Benedicks[7] it had been established that it is possible to treat thin specimens chemically so as to isolate *in situ* their content of non-metallic inclusions. The method used by Skapski, however, being based on gaseous reactions, necessitated a complicated apparatus for vacuum work, and a considerable experimental skill. There is ample evidence that the residues finally obtained correspond to actual inclusions (Al_2O_3, SiO_2), but it is possible that some inclusions may have been attacked, or even removed, by the chemical treatment (chlorine and hydrogen chloride at 600–850° C.).

The problem is to find a simple method that can be used more easily in ordinary laboratory practice.

EXPERIMENTAL PROCEDURE

Materials Used

The same steels, *A*, *B*, and *C*, were used as in the previous work. Details of their original state and composition are as follows :

	Steel *A* Cold-Rolled Sheet	Steel *B* "Capsule Iron"	Steel *C* AlN-Rich Iron
Original thickness, mm....	0·02	0·08	25·5
Composition, % :			
Carbon	0·07	0·07	0·09
Silicon	Trace	Trace	0·18
Manganese	0·12	0·33	0·30
Phosphorus	0·013	0·010	0·009
Sulphur	0·013	0·020	0·07
Nitrogen	...	...	0·010

For the chemical treatment steel *A* was used in its primary state, steel *B*, a basic open-hearth steel, was milled and cut down to 0·020–0·030 mm. thick, and steel *C* was sawed, milled, and micro-cut down to 0·02 mm. Steel *C* was prepared at Fagersta by H. Kjerrman.

Fixing Methods

(*a*) The first method of fixing the specimen was as follows : A glass slide (about 28 × 48 mm.) was thoroughly cleaned and (locally) coated with zapon lac ; one side of the specimen was similarly treated. After drying, the specimen was fixed on to the coated spot by means of a trace of zapon lac. This method worked well in many cases (at constant temperature), but with a prolonged attack the zapon coating had a tendency to loosen from the glass.

(*b*) To avoid this the specimen was placed on a zapon lac coating, as described, but was also held by a small glass ring, pressed against the specimen by means of a glass fibre, kept in place by two small silver holders, as seen in Fig. 29. This arrangement worked quite well, but the glass ring caused some trouble during washing.

(*c*) The specimen was simply placed upon the zapon coating ; the adhesive forces proved great enough to fix the specimen at the same position on washing, provided that this was carried out very carefully.

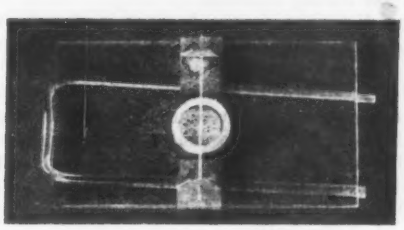


Fig. 29—Glass slide, holding specimens in position for chemical treatment (actual size)

(*d*) In certain cases, when the organic coating might have influenced the character of the residue, the specimen was placed directly on to the glass without any intermediate substance. This was found to be satisfactory when the residue had the property of forming a thin, sponge-like skeleton.

Etching Reagents

Nitric acid (about 1% in etanol) was tried for dissolving the iron, but was found unsuitable, owing to the formation of gas bubbles. Iodine ('iodine tincture'—10% I, 4% KI in etanol, containing some water) was found to react extremely slowly.

Bromine was found to be an excellent, quick-reacting reagent, particularly in metanol solution. The following times were requisite for the dissolution of specimens of steel *A* (0·02 mm.):

Bromine, %	Dissolution Time, hr.
0·5	>24
1·0	3·5
2·0	2
5·0	0·16

A 1% solution was generally used. Solutions of bromine and etanol required about double the times given above. Again, frequent use was made of a 1% solution, but other concentrations were also used. Solutions of bromine in benzol were found unsuitable, iron bromide apparently not having the necessary solubility in benzol.

METALLOGRAPHIC OBSERVATIONS

The observations made during the chemical treatment of the three steels *A*, *B*, and *C*, and the metallographic conclusions drawn, are reported briefly in the following paragraphs.

Steel *A*

Steel *A* was used in its primary state, without annealing. Figure 21 shows the first stage of eliminating the iron ; in the interior of the sample much iron remains. The borders, being most exposed to the reagent, have already been freed from metallic iron. It will be seen that the borders are preserved essentially *in situ*, and form a coherent film, the limits of which are well marked. This is due to a slight rolling-up, as can be seen in the microscope when properly focused. The rolling-up, although rather slight here, shows that there is a definite coherence in the residue. Full evidence of this fact is given by Fig. 22, where a considerable part of the residue is folded. The sample was quite free, without any foreign matter, and was etched with 8% bromine-etanol at 21° C. ; the folding took place during washing.

Some disturbances can be seen in the right-hand part of Fig. 22 : small parts of the residue exhibit slight damage, and a local rolling-up. In Fig. 23 an undamaged part of the same residue is reproduced at a magnification thirteen times higher (× 600). Even here no details are visible which might explain the coherence, The black, opaque inclusions in Fig. 23 are extremely numerous and may be (Fe, Mn) spinel, ((Fe, Mn) Al_2O_4), or possibly iron oxidule (Fe, Mn) O (*cf.* H. Löfquist[16]).

Some Mg-spinel ($MgAl_2O_4$) is also present, revealed as translucent octahedrons with a high refraction. It may be added that the profusion of inclusions to be seen in Fig. 23 (after 8 hr. reaction in 8% bromine-etanol) would not be expected with a more energetic reagent. Similar tests have shown that the same reagent used over several days does not alter perceptibly the appearance of Fig. 23.

Steel *B*

Steel *B* (*see* Fig. 24) produced a more bulky residue than steel *A** and with a still greater coherence. The specimen was treated on a zapon coating, but the residue had been moving freely in the liquid and had become broken into fragments, one of which is shown in Fig. 24. The bulky character of the residue of *B* is seen at slightly higher magnification (× 230) in Fig. 25. The inclusions (a darkish brown) seem partly to form fairly large crystals (or dendrites). The large amount of inclusions is probably related to the high upper yield point of steel *B*.[17]

With high magnification (Leitz $\frac{1}{16}$-in. immersion objective, 1·30 aperture, cedar oil between condenser and slide), Fig. 26 (×1250)† was obtained.

The greater part of the inclusions were brownish in colour, somewhat translucent, with rounded, partly rectilinear edges. Owing to the higher manganese content (0·33%), this dark mineral is supposed to be oxidule (Mn, Fe) O, with more or less (Mn, Fe) spinel, (Mn, Fe) (Al_2O_4). It is in appearance very similar to a micrograph of H. Löfquist (Fig. 27[16]). Besides the dark mineral, a fairly large amount of well-crystallized translucent (greenish) Mg spinel is present. As pointed out by Löfquist,[16] such translucent spinel crystals were first observed in electrolytically extracted inclusions by Treje and Benedicks.[18]

THE COHERENCE OF THE RESIDUE

Steels *A* and *B*

A most interesting point is the striking coherence which has been found to exist in the residues of steels *A* and *B*. This may be due to one or more of the following factors :

(1) An influence of the supporting zapon lac.

(2) The possibility of a condensation product being formed by the organic solvent.

(3) The formation of oxide layers on the two surfaces.

(4) A substance absorbed in the grain boundaries.

Item (1) may be excluded at once, as the dissolving reaction, when carried out without any foreign substance present, that is, directly on glass, gave the same result (*see* Fig. 22). Item (2) is not impossible, as, in the presence of bromine, an oxidation of etanol

* This may be due partly to the slightly greater thickness of the specimen of steel *B* (0·02–0·03 mm.).

† Figure 26 was obtained with an ordinary vertical mineralogical microscope (R. Fuess), on which the camera (Leitz, " Makam ") was set in place of the eyepiece. The whole apparatus was greatly affected by vibration from traffic. This difficulty was entirely overcome by the following device : A 12-mm. square brass rod leaned against the camera at an angle of 45°, the lower end resting against a heavy lead block. The friction between the rod and the camera eliminated any sensible vibration. Figure 26 was obtained in this way and is remarkably sharp ; Fig. 27 was taken without this damping device and is much inferior, all small details being absent.

(to aldehyde) could occur and be followed by a condensation process to some high molecular substance. Professor J. Tandberg has pointed out that such a condensation product would diffuse into the liquid; hence it is quite improbable that it would be able to act as a glue for the residue. Experimental control was, however, desirable, and it was for that reason that solutions of metanol—with which a condensation process is still less likely—were used.

Bromine-metanol acted in a similar way to bromine-etanol (*cf.* Fig. 21); the coherence of the residue may have been smaller than with etanol, but this may be due entirely to the greater dissolution speed of the metanol solutions.

Item (3), the presence of an 'invisible' oxydic surface layer not dissolved by the bromine, would, of course, explain a certain coherence of the residue, but, in this case, almost all the inclusions would be located in the same bottom plane (that of the slide). In fact, the particles differ considerably in the height of their positions. In a sample of steel *B*, of initial thickness 20μ, when the iron was dissolved a spongy residue was obtained in which distinct particles could be focused at least up to 10μ. Similar observations were made on steel *A*.

If item (3) be true, oxydic layers would occur also in the grain boundaries. This, however, is equivalent to item (4). Since good reasons exist against items (1), (2), and (3), item (4) must be assumed to be true.

The enormous coherence observed in steels *A* and *B* points decidedly towards the existence of adsorbed layers or other connecting bridges, but these are not visible in the optical microscope.

Steel *C*

Small, free, rounded, transparent grains (about 1 to 2μ dia.) occur frequently in the residue obtained from steel *C* (rich in AlN). They are probably pure alumina (Al_2O_3; *cf* H. Löfquist, Fig. 16[16]). No other sharply defined inclusions were observed, but the residue contained a large quantity of irregular brownish fields, generally sharply defined on one side and the remainder blurred (*see* Fig. 28). These typical fields may be interpreted as thin films rolled up irregularly at the dissolution of the iron. No details could be observed on the occasional unrolled spots (× 1250, aperture 1·30). These thin flat parts are visible because of a stray light absorption.

The brownish substance may be assumed to be aluminium nitride (AlN)—it occurs in a fairly large quantity according to the analysis—or a decomposition product closely related to AlN.*

In the examination of steels *A* and *B*, the "missing link" was the invisibility of the film; its presence could be concluded only by the mechanical coherence of the residue. This "missing link" has been given by steel *C*, the visibility obviously being due to a strong light absorption in the AlN film, which exists either unchanged or decomposed.

Because of the theoretical and practical importance of this result, continued researches are desirable. The micro-cutting method, now comparatively well advanced, and the dissolving method, not as well advanced, but quite usable, should remove the experimental difficulties of the problem.

* A certain amount of colloidal carbon may also be present as the decomposition product of Fe_3C; this, in a simple way, would account for the dark colour. If, on the other hand, this assumption is correct, coherent colloidal carbon would be expected to occur similarly in steels *A* and *B*, which is not the case. Hence colloidal carbon alone does not seem to form a visible film, but the AlN film may contain some carbon.

SUMMARY AND CONCLUSIONS

PREPARATION OF THIN SPECIMENS

The isolation of non-metallic inclusions *in situ* requires a process of cutting thin sheets, about 0·02 mm. thick, from massive steel pieces. A precision bench milling machine is not excluded for this purpose, but there exists the difficulty of obtaining good, resistant, well-centring milling cutters. Hence, a single cutting edge, as used in the microtome, appears preferable.

A special investigation has been made to determine a tool shape suitable for steel (the microtome was previously used only for soft metals). Starting with the well-known behaviour of metals on shearing, an exposition has been made of the generation of chips in relation to the tool shape. To produce a really plane surface, a lip angle of somewhat less than 90° was the most suitable. It is important that the elastic centre of the tool is situated in a plane perpendicular to the plane to be shaped, and passing through the edge of the tool (Fig. 2).

A suitable cutting fluid is described. The qualities of the surfaces produced have been studied, using a micro-cator, and by means of photomicrographs. The soldering of the thin specimens in position has demanded considerable attention.

CHEMICAL ISOLATION OF NON-METALLIC INCLUSIONS

Different methods were used for fixing the specimens on the supporting glass slide for the chemical treatment. For preference, the specimen was fixed by means of zapon lac, but specimens without any means of fixing were also used. The treatment is facilitated by the fact that the residue frequently possesses a fairly high coherence.

Low-carbon steels were used. As dissolving agent, bromine dissolved in etanol or metanol was found to be satisfactory. The time of reaction is easily controlled and no gas is formed.

The most striking feature was the coherence of the residue, which occurred in the three steels investigated.

Steel *C*, possessing an unusually high content of AlN—the substance which was at first made responsible for prohibiting grain growth—actually showed visible (light-absorbing) thin films in great quantity. This supports the statement of Bo Ljunggren,[19] who, using a completely different method, agreed with Benedicks and Löfquist's theory of "a molecular enrichment of nitride in the boundaries."

Acknowledgments

The authors wish to express their gratitude to the Swedish Government for the use of laboratory space, and for the award, on the instigation of Statens

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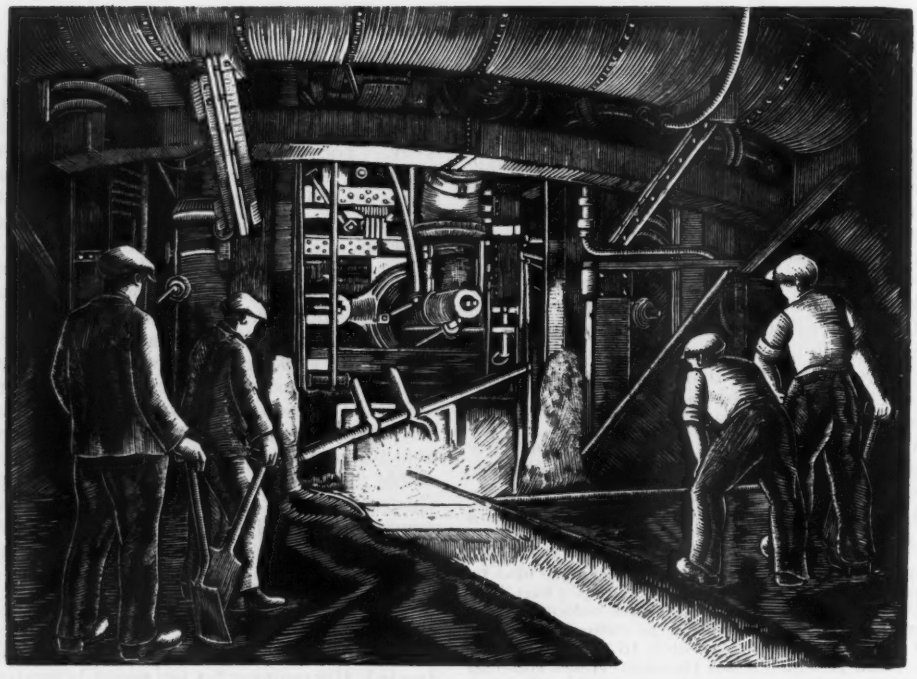


Running liquid iron from a blast-furnace—from the original woodcut by Viva Talbot

PROCEEDINGS OF THE INSTITUTE

REPORTS OF COUNCIL - OFFICIAL NOTICES

AUTUMN GENERAL MEETING, 1948

THE AUTUMN GENERAL MEETING OF THE IRON AND STEEL INSTITUTE was held on Wednesday and Thursday, 10th and 11th November, 1948, at the Offices of the Institute, 4, Grosvenor Gardens, London, S.W.1. The President, Sir ANDREW MCCANCE, LL.D., D.Sc., F.R.S., was in the Chair at the first three sessions, and Dr. C. H. DESCH, F.R.S., Past-President, on the Thursday afternoon.

Sessions were held from 10.0 A.M. to 1.15 P.M. and from 2.30 P.M. to 5.0 P.M. on both days, and buffet luncheons were provided in the Library of the Institute.

The Minutes of the previous meeting, held in London on 5th and 6th May, 1948, were taken as read and confirmed.

OBITUARY

The **President** (Sir Andrew McCance, F.R.S.): It is with regret that I have to report the deaths of some prominent Members of the Institute which have occurred since the Annual General Meeting in May:

Sir W. Peter Rylands, Bt., Past-President (Member 1901, Member of Council 1913, Vice-President 1921, President 1926–27. Date of death, 22nd October, 1948).

Sir Peter B. Brown, Honorary Vice-President (Member 1899, Member of Council 1933, Vice-President 1943, Honorary Vice-President 1945. Date of death, 12th October, 1948).

Mr. Cyrus Braby (Member since 1889. Date of death, 20th May, 1948).

Mr. Harry Brearley (Member since 1905, Bessemer Medallist 1920, Honorary Member 1942. Date of death, 14th July, 1948).

The Rt. Hon. Viscount Greenwood, P.C., K.C. (Member since 1939. Date of death, 10th September, 1948).

The Members stood for a few moments in silence as a token of respect.

WELCOME TO MEMBERS AND VISITORS

The **President**: I have pleasure in welcoming the Members and visitors from overseas, and in particular I offer a warm welcome to Mr. Christian Sommerfelt, of Norway, who has very kindly undertaken the duty of making the arrangements for our summer visit to his country next year.

PROPOSED ALTERATIONS TO BYE-LAWS

In accordance with Bye-law No. 20, the President gave notice that it was the intention of the Council at the Annual General Meeting in 1949 to propose alterations to Bye-laws Nos. 3, 21, 35, and 36. The resolution, which was printed in the circular calling the Meeting, is as follows:

"That the Bye-laws of the Institute be altered in manner following, that is to say

(1) In Bye-law 3 by adding thereto the words following:—

"It shall also be within the province of the Council to elect Associate Members. The Council shall have power from time to time to make regulations (not inconsistent with anything in these Bye-laws) for defining the status rights and obligations of associate members, for prescribing the ages and qualifications of candidates for associate membership and providing for the transfer of associate members to ordinary membership of the Institute including the fixing of an entrance fee to be payable on such transfer and for the waiving of the same at the discretion of the Council.

Except where the context otherwise requires, the word "Members" where used in these Bye-laws shall include members of all classes Provided that an associate member shall not have the right to sign a requisition for a general meeting or to vote at such a meeting or to sign a recommendation for admission to membership or to nominate candidates for election as officers."

(2) By deleting Bye-law 21 and by substituting therefore the following new Bye-law:—

21. "The entrance fee payable by members on election shall be such sum, if any, as the Council shall from time to time determine.

Until otherwise determined by the Council and sanctioned by a resolution passed at either the Annual General Meeting or the General Meeting held in the Autumn of each year, at which notice of intention to propose the same shall be given:

(*a*) The annual subscription payable by ordinary members shall be £4 4*s*. 0*d*. and by associate members shall be £1 15*s*. 0*d*.

(*b*) Any ordinary member whose subscription is not in arrear may at any time before the 30th

June in any year, or if elected after that date in the year, within one month of his election, compound for his subscription for subsequent years on payment according to the following scale :

Up to 29 years of age	£70
From 30 to 39 years of age	£63
,, 40 to 49 ,, ,, ,, ...	£56
,, 50 to 59 ,, ,, ,, ...	£49
,, 60 years of age and upwards ...	£42

Provided that the adoption of this Bye-law shall not prejudice the validity of any composition duly effected according to the scale set out in the Bye-law which is hereby revoked.

Provided also that in the case of any member or associate member who is also a member of the Institute of Metals or of the Institution of Metallurgists or of any other Institute or Society (whether in or out of the United Kingdom) which the Council shall from time to time declare to be a Kindred Society for the purpose of this Bye-law, the Council shall have power to accept from such member or associate member such reduced subscription under such conditions as it shall from time to time think fit."

(3) By deleting from Bye-law 35 the words " ordinary or honorary " wherever these words occur and also the words " whether ordinary or honorary."

(4) By deleting from Bye-law 36 the words " honorary members and honorary vice-presidents " and the words " honorary members or honorary vice-presidents."

The **President** : The effect of these changes is to make provision for the class of Associate Members and to give authority to the Council to change subscription rates, subject to approval by Members at a General Meeting.

You will know from the letter (printed in the November, 1948, issue of the *Journal*, page 315) which has been sent to all Members that the Council thinks it necessary for subscriptions to be increased from the beginning of next year. The increase in the case of Members will be one guinea and in the case of Associates ten shillings a year, thus bringing subscriptions into line with those payable to the Institute of Metals. The reductions for Joint Membership will hold good and it is proposed to abolish the entrance fee. The maximum age of Associate Membership will be reduced to 25, except in the case of those who have already exceeded that age.

The Council regrets the need to increase subscriptions, but, under the circumstances of the present day, considers this unavoidable.

I thought that in recommending these changes to you I had a personal responsibility, as President, to see that the work of the Institute was being carried out efficiently and economically. Accordingly, I arranged for a Committee to carry out a searching examination. As a result, substantial economies have been made and other economies will be made in the immediate future. My colleagues on the Council, and I, are satisfied that the money entrusted to our care is being well spent ; and we are satisfied also that the proposed increases in subscriptions are necessary if the finances of the Institute are to be put into a satisfactory condition.

HONORARY TREASURERSHIP

The **President** : I have to announce that Mr. R. G. Lyttelton, who has been Honorary Treasurer for the last seven years, wishes, owing to other duties which he has undertaken, to tender his resignation as Honorary Treasurer, from the end of this year. The Council, accordingly, has nominated Mr. James Mitchell (Vice-President) to be Honorary Treasurer from that date.

As a token of their appreciation to Mr. Lyttelton for the work which he has carried out the Council has elected him a Vice-President. I am sure that these changes will have your approval. I know that I shall be responding to your wishes if I express our gratitude to Mr. Lyttelton for the great amount of work which he has undertaken in connection with the Institute during the past seven years. (*Applause.*)

CHANGES ON THE COUNCIL

The **President** : I have to announce that the Council has elected Mr. Edward Senior to be an Honorary Member of Council in view of his forthcoming appointment as Commercial Director of the British Iron and Steel Federation.

This position has been rendered vacant by the resignation of Sir John Duncanson, who was an Honorary Member of Council. The Council has elected Sir John Duncanson an Honorary Vice-President, in recognition of the services which he has given to the industry and to the Institute. I am sure that that will meet with your approval. (*Applause.*)

The **Secretary** (Mr. K. Headlam-Morley) : I have to announce the following changes on the Council, made since the last General Meeting in May of this year :

Mr. G. Steel has been elected a Vice-President, and Mr. W. Barr a Member of Council.

The following Presidents of Affiliated Local Societies have become Honorary Members of Council for their periods of office :

Mr. F. Shepherd, President of the Cleveland Institution of Engineers, in place of Mr. Chris Moody.

Mr. W. R. Berry, President of the Leeds Metallurgical Society, in place of Professor A. Preece.

Mr. H. M. Henderson, President of the Lincolnshire Iron and Steel Institute, in place of Mr. J. B. R. Brooke.

Mr. T. J. Canning, President of the Swansea and District Metallurgical Society, in place of Mr. E. A. Davies.

Mr. A. H. Goodger, President of the Manchester Metallurgical Society, in view of the affiliation of that Society, as announced at the last meeting.

I have also to give notice that the following are due to retire at the next Annual General Meeting and are eligible for re-election :

Vice-Presidents—Captain H. Leighton Davies, Mr. G. H. Latham, and Mr. J. Sinclair Kerr.

Members of Council—Mr. T. Jolly, Mr. F. Saniter, Mr. W. F. Cartwright, Dr. J. W. Jenkin, and Sir Arthur Matthews.

MEETINGS IN 1949

The **Secretary** : The dates of meetings during 1949 have been fixed as follows :

Annual General Meeting : Wednesday and Thursday, 27th and 28th April.

Special Summer Meeting in Norway : Saturday, 28th May, to Tuesday, 7th June, inclusive.

Autumn General Meeting : Thursday and Friday, 10th and 11th November.

The Council have decided to organize, or to take part in organizing, in 1950, the following two Congresses, of which I give preliminary notice : an International Corrosion Conference, and a Symposium on Steels and Alloys for Gas Turbines.

ANDREW CARNEGIE SCHOLARSHIPS

The **Secretary** : Andrew Carnegie Scholarships have been awarded as follows :

To Mr. N. H. Polakowski, for a research under the general heading of " *The Hot and Cold Deformation*

of Steels and other Metals," at University College, Swansea.

To Mr. W. J. Williams, for a research on "*The Individual Influence of very Low Percentages of Sulphur, Manganese, Silicon, Phosphorus, and Aluminium, on the Microstructure of Pure Iron–Carbon Alloys*," to be carried out at the Laboratories of the British Cast Iron Research Association.

MOND NICKEL FELLOWSHIPS IN METALLURGY

The **Secretary** : The following Mond Nickel Fellowships in Metallurgy have been awarded for 1948 :

To Mr. G. S. Campbell (Plessey Co., Ltd.), for the study of the organization from research to large-scale production of specialized metallurgical industries in the United States of America and Canada.

To Mr. S. J. Garvin (Murex, Ltd.), for the study of the application of sponsored research and administrative methods employed in the powder metallurgical industries of the United States of America.

To Mr. A. I. Nussbaum (Thomas Firth and John Brown, Ltd.), for the study of the application of rolling mill research, mill plant development, and theory of rolling, to the manufacture of rolled steel products in the United States of America.

BALLOT FOR THE ELECTION OF MEMBERS AND ASSOCIATES

Dr. M. L. BECKER (London) and Dr. H. HARRIS (Renfrew), who were appointed scrutineers of the ballot, reported that the following one hundred and fifty Members and eighty-six Associates had been elected :

Members

Abbey, Horace Reginald (Sheffield) ; **Acland,** Thomas St. Hill (Sheffield) ; **Andrew,** Sydney (Shotton, near Chester) ; **Atkinson,** George (Sheffield) ; **Bablik,** *Dr. Ing.* Heinz (Vienna, Austria) ; **Bénard,** *Professor* Jacques (Lyons, France) ; **Bevan,** John Lewis Maybery, B.A., G.I.Mech.E. (Briton Ferry, Glam.) ; **Bhatawadekar,** Raghunath Govind, B.A.(Hons.), B.Sc., B.Met. (New Delhi, India) ; **Bishop,** Tom, B.Met.(Hons.), A.I.M. (London) ; **Blakeborough,** E. (Stockton-on-Tees) , **Blench,** S. (Consett) ; **Bone,** Victor William (Lincoln) ; **Booth,** Cyril, Ph.D., M.Met. (Worksop, Notts.) ; **Booth,** J. R. (Middlesbrough) ; **Bowes,** E. A., B.Sc. (Consett) ; **Bowler,** Ronald Frederick (Sheffield) ; **Briggs,** Peter Richard Ashworth, B.Sc. (Sheffield) ; **Brisby,** *Ing.Dipl.* Michael Douglas James (London) ; **Broughton,** B. (Hartlepool) ; **Brutcher,** Henry Eric (Altadena, California, U.S.A.) ; **Buttler,** Maurice William, Assoc.Met. (Sheffield) ; **Chapman,** Herbert Alec (London) ; **Chrisp,** J. (Consett) ; **Clark,** J. G. (Hartlepool) ; **Clarke,** J. (Consett) ; **Cockerline,** G. A. (Stockton-on-Tees) ; **Coldwell Horsfall,** John Henry (Birmingham) ; **Cole,** T. (Consett) ; **Collins,** J. (Hartlepool) ; **Colombelli,** Ernesto (São Paulo, Brazil) ; **Contractor,** G. P., M.Sc., Ph.D. (Jamshedpur, India) ; **Coomes,** Harold Burdett (Corby) ; **Cox,** Ernest Frank (London) ; **Danielsson,** Christer (Domnarvet, Sweden) ; **De Brouckere,** Lucia, D.Sc. (Brussels, Belgium) ; **Denton,** William Henry (Sheffield) ; **Dimmock,** Roy Henry (Gowerton, Glam.) ; **Downie,** T. (Stockton-on-Tees) ; **Elkington,** F. (Hartlepool) ; **Evans,** Frederick Aubrey (Lymington, Hants.) ; **Firth,** T. G. (Consett) ; **Flux,** John Henry, B.Sc.(Eng.) (Birmingham) ; **Forbes,** Colin Leslie, B.Sc., M.I.Mech.E. (Leeds) ; **Foster,** Leslie Charles (Middlesbrough) ; **Galliford,** Alfred Edward Bruce (Sunderland) ; **Gamwell,** Alfred (Liverpool) ; **Geerlings,** *Dr.Ir.* H. G. (Amsterdam, Holland) ; **Gilhespy,** William Mayors (Sheffield) ; **Godbehere,** Alfred Shadbach, Assoc.Met. (Sheffield) ; **Godfroid,** Henri (Paris, France) ; **Goodwin,** Charles Raymond (Middlesbrough) ; **Goodwin,** Edward Charles (Gateshead) ; **Grist,** Charles Harry (Wolverhampton) ; **Gundry,** Walter, G.I.Mech.E. (Sheffield) ; **Gupta,** Hari Shanker, B.Sc.(Met.) (Jubbulpore, India) ; **Haker,** John (Johannesburg, South Africa) ; **Hanlon,** Norman (Middlesbrough) ; **Harding,** Benjamin Walton (London) ; **Hartley,** H., D.Sc. (Birmingham) ; **Hawkes,** John Marsh, Ph.D., B.Sc. (London) ; **Henthorn,** Robert Saxon (Shotton, near Chester) ; **Herty,** Charles H., jun., D.Sc., M.S., B.S. (Bethlehem, Pa., U.S.A.) ; **Higginbotham,** William Henry (Sheffield) ; **Horrell,** Herbert Guy (Germiston, Transvaal, South Africa) ; **Howard,** A. P. (West Hartlepool) ; **Huber,** Max Georg (Schaffhausen, Switzerland) ; **Hughes,** Ernest (Sheffield) ; **Ibbotson,** John Davis (Loxley, near Sheffield) ; **Jafet,** Roberto Nami (São Paulo, Brazil) ; **Jarvis,** Evan (Scunthorpe) ; **Johnston,** Dominick, M.Sc. (Leeds) ; **Jones,** James Edward (Shotton, near Chester) ; **Karnad,** Shamarao Sanjivarao, B.Eng. (Bombay, India) ; **Kempson,** Jarry Thomas (Birmingham) ; **Kidman,** Lawrence, Assoc.Met. (Sheffield) ; **Kirkpatrick,** John William (Redcar, Yorks.) ; **Kirkup,** T. (Hartlepool) ; **Kirkwood,** Alexander (Motherwell, Lanarkshire) ; **Lanari,** Roberto (São Paulo, Brazil) ; **Lastra y Soubrier,** Ricardo de la (San Fernando, Cadiz, Spain) ; **Lay,** James Owen, A.R.I.C. (London) ; **Le Bailly,** Louis Edward Stewart Holland (London) ; **Light,** James O., B.S.(Met.) (Lorain, Ohio, U.S.A.) ; **Linstead,** Charles Caleb (Sheffield) ; **Lisle,** E. B. (Consett) ; **Loxton,** Ralph Dingle, B.Sc. (Sheffield) ; **McKinney,** R. (Consett) ; **MacDonald,** Norman Davidson (Scunthorpe) ; **MacMillan,** James Arthur (Midland, Pa., U.S.A.) ; **Marshall,** William Byers (Redcar, Yorks.) ; **Marzke,** Oscar T., B.S., Sc.D. (Washington, D.C., U.S.A.) ; **Meynell,** Eric (Middlesbrough) ; **Michie,** Percy (Sheffield) ; **Mirando,** Augusto (Madrid, Spain) ; **Mitchell,** John Frederick Roy (London) ; **Mitchell,** Reginald Gordon, F.R.I.C., F.Inst.Pet. (London) ; **Moore,** John (London) ; **Morley,** Allen Derek (Sheffield) ; **Moss,** J. F. C. (Consett) ; **Muntz,** Cecil Dudley, M.A., M.Inst.C.E., A.M.I.Mech.E. (London) ; **Nag,** Sushil Kumar, B.Sc. (West Bengal, India) ; **Osgerby,** William Edward (South Bank, Middlesbrough) ; **Parish,** Herbert, A.M.I.Mech.E. (Birmingham) ; **Pears,** George Reginald Witton, A.Met., A.I.M. (South Bank, Middlesbrough) ; **Pereira Pinto,** Francisco F., M.Sc. (Rio de Janeiro, Brazil) ; **Platts,** Francis Arthur (Manchester) ; **Porter,** Charles Stephen (Sunderland) ; **Postle,** J. (Consett) ; **Pufahl,** Hans R. (New York, N.Y., U.S.A.) ; **Purdie,** W. Neil (West Hartlepool) ; **Rao,** Tanguturi Narasimha (Madras, India) ; **Reed,** W. S. (Consett) ; **Richards,** Morgan (Middlesbrough) ; **Ridgewell,** Percy (Salfords, Surrey) ; **Ridley,** A. H. (Stockton-on-Tees) ; **Roberts,** T. G. (West Hartlepool) ; **Robertson,** T. (Stockton-on-Tees) ; **Roca Soler,** José (Gavá (Province Barcelona), Spain) ; **Ruhnke,** D. H. (Massillon, Ohio, U.S.A.) ; **Scortecci,** *Professor* Antonio (Genova-Cornigliano, Italy) ; **Scott,** S., G.I.Mech.E. (West Hartlepool) ; **Seymour,** W. (Consett) ; **Sheen,** Maurice K. (Corby) ; **Shoosmith,** G. T., M.A., A.M.Inst.C.E., M.I.Mech.E. (Erith, Kent) ; **Shore,** L. (Consett) ; **Sisto,** Joseph A. (New York, N.Y., U.S.A.) ; **Smart,** J. (Consett) ; **Smith,** Joseph (Shotton, near Chester) ; **Smith,** Peter Drury, B.Sc.(Eng.) (Redlynch, Salisbury) ; **Smith,** Victor, B.Sc.(Tech.) (Corby) ; **Stanage,** Robert (Middlesbrough) ; **Stockdale,** W. (Consett) ; **Stocks,** Wilfred (Worksop, Notts.) ; **Thomas,** A. N. (Middlesbrough) ; **Thomas,** William George, A.M.I.E.E. (Sheffield) ; **Torras,** Juan (Barcelona, Spain) ; **Turner,** F. (Consett) ; **Turner,** William Arthur (Royston, Herts.) ; **Upton,** Vincent Edwin (Manchester) ; **Walford,** John Graham, B.Sc.(Hons.) (Sheffield) ; **Waring,** Henry William Allen (East Moors, Cardiff) ; **Watson,** P., B.Sc., G.I.Mech.E. (West Hartlepool) ; **Weir,** Robert Canning (Vanderbijl Park, Transvaal, South Africa) ; **Whitehead,** Ernest, Assoc.Met. (Scunthorpe) ; **Williams,** Norman Thomas (Corby) ; **Williamson,** Lawrence Joseph, Assoc.Met. (Sheffield) ; **Winkler,** Theodore Boger, B.S., Sc.D. (Bethlehem, Pa., U.S.A.) ; **Wolverson,** Tom (Stockton-on-Tees) ; **Wyss,** Urs (Gerlafingen, Switzerland) ; **Zingg,** *Dr. Ing.* Ernest (Winterthur, Switzerland).

Associates

Ackroyd, Dennis (Huddersfield) ; **Atkinson,** George Dennis (Newcastle-on-Tyne) ; **Bailey,** Francis Walter John, B.Sc. (Hons. Met.) (Birmingham) ; **Baker,** Hugh (Rodley, near Leeds) ; **Banks,** John F., G.I.Mech.E. (Middlesbrough) ; **Bellingham,** Laurie (Shotton, near Chester) ; **Broadley,** William (Dukinfield, Cheshire) ; **Brown,** Anthony (Stocksbridge, near Sheffield) ; **Brown,** David Charles (Newcastle-on-Tyne) ; **Brownlee,** Malcolm (South Bank, Middlesbrough) ; **Bullock,** William John (Devonport) ; **Burke,** James (Liverpool) ; **Burrill,** William James (Newcastle-on-Tyne) ; **Catterall,** John Ashley (London) ; **Coidan,** Ralph Julian, B.Sc. (Harborough, Leics.) ; **Collins,** John Charles (Sheffield) ; **Cork,** John Samuel (Shotton, near Chester) ; **Cotterill,** D. (Consett) ;

Cowley, Donald Kenneth (Isleworth, Middlesex); **Demain,** William (London); **Dennis,** William Eric (Newcastle-on-Tyne); **Descovich,** Sergio (Genova-Cornigliano, Italy); **Dowswell,** William Rickardes (Shotton, near Chester); **Duckworth,** Albert (Manchester); **Dunger,** Colin (Middlesbrough); **Dunmore,** Owen J. (London); **Eastwood,** Harry (Manchester); **Edmonds,** Ernest (Durham); **Elliott,** John Eric, B.Sc.(Hons. Met.) (Birmingham); **Entwisle,** Anthony Roger, B.A.(Hons.) (Cambridge); **Evans,** David John Ivor (London); **Farmery,** Harold Keith (Cambridge); **Farthing,** T. W., B.A. (Cambridge); **Feaver,** Alan Rayfield (Middlesbrough); **Gallacher,** William (Waltham Abbey, Essex); **Gibson,** Norman (Newcastle-on-Tyne); **Gould,** Joseph William (Middlesbrough); **Gower,** Robert (Stourport-on-Severn, Worcs.); **Grassam,** Bryan William, B.A. (Cambridge); **Harrison,** Vincent (Middlesbrough); **Harrison,** W. G. (Consett); **Higgs,** John Yuill, B.Sc. (Hons. Met.) (Perivale, Middlesex); **Hiscock,** Sidney Alfred, B.Sc. (Harlesden, Middlesex); **Hopkins,** John Leighton (London); **Hoskins,** John Albert, B.Sc.(Met.) (Rotherham); **Hughes,** James Ernest (London); **Hume,** W. C. (Consett); **Jackson,** Matthew Derrick (Sheffield); **James,** Kenneth Henry (London); **Jepson,** Malcolm Douglas, M.Sc. (Manchester); **Jones,** Richard Maxwell, B.A.(Hons.) (Cambridge); **Killington,** Albert James (London); **Layland,** Robert Alan (Tipton, Staffs.); **Littlewood,** Geoffrey (Lockwood, near Huddersfield); **Lolley,** James (Manchester); **Long,** Edward Anthony (Middlesbrough); **Macfarlane,** Thomas Gracie (Glasgow); **Menzies,** James Aitken (Glasgow); **Murad,** Abu Bakr, B.Sc. (Glasgow); **Naghaudhuri,** S., B.Sc. (Met.) (West Bengal, India); **Noble,** R.E. (Consett); **Nunn,** Peter Hubert (Newcastle-on-Tyne); **Osborne,** David Gerald (London); **Palit,** Kanai Lal, B.Sc., B.Met. (Kulti, West Bengal, India); **Parry,** Paul I., B.Eng.(Hons.Met.) (Rugby); **Pattinson,** M. (Consett); **Peacock,** Frederick Brian (Middlesbrough); **Porter,** Frank Cecil, B.A. (Cambridge); **Quigley,** J. M. (Consett); **Radcliffe,** Stanley Victor (Liverpool); **Reed,** A. L. (Consett); **Sandilands,** W. A. (Halifax); **Saxena,** Mahesh Narain, B.Sc. (Benares, India); **Schofield,** William Hugh (Middlesbrough); **Sharpe,** Roy Samuel, B.Sc.(Hons.), L.I.M. (Bristol); **Skinner,** Richard Antony, B.Sc. (Tadworth, Surrey); **Stephenson,** Victor (Middlesbrough); **Sudarsanan,** Andipat Pavithran, B.A. (Leeds); **Taher,** Samir, B.Sc. (Glasgow); **Taylor,** John Welsh (Glasgow); **Walker,** L. (Middlesbrough); **Watson,** Eric Herbert (Sheffield); **Whitehead,** Derek James, B.Sc.(Hons.) (Clifton Junction, near Manchester); **Willis-Jones,** E., B.Sc. (Swansea); **Yarworth,** Norman (Sheffield); **Young,** Kenneth Owen (Huddersfield).

The **President** announced that the total membership of the Institute was 4911.

PRESENTATION OF PAPERS

The following papers were presented and discussed (the date of publication is shown in italics):

Wednesday, 10th November, 1948

Morning Session

"A Note on the Varying-Turbulence Cowper Stove. The Denain-Anzin Tests and the C.S.I. Standard Cowper Stove," by D. Petit. (*October,* 1948.)

"Magnetic Concentration Experiments Upon Iron Ores Used in North Lincolnshire Practice," by L. Reeve. (*July,* 1948.)

"The Work and Organization of a Statistical Department in Heavy Industry, with Particular Reference to the Steel Industry," by A. W. Swan. (*September,* 1948.)

Afternoon Session

"The Application of Oxygen-Enrichment to Side-Blown-Converter Practice," by J. L. Harrison, W. C. Newell, and A. Hartley. (*July,* 1948.)

"Development of an Improved Basic Bessemer Steel," by H. A. Dickie. (*August,* 1948.)

"Ingot Structures in a Series from Rimmed to Killed Steels Made from the Same Cast," by P. M. Macnair. (*October,* 1948.)

Thursday, 11th November, 1948

Morning Session

"Ingot Surface Defects in Structural Steels," by L. Reeve. (*October,* 1948.)

"Open-Hearth-Furnace Instrumentation," by E. Rogers (*September,* 1948), *discussed jointly with* "First Report of the Open-Hearth Instruments Sub-Committee," by F. L. Robertson. (*September,* 1948.)

"Rapid Estimation of Slag Basicity," by W. A. Smith, J. Monaghan, and W. Hay. (*October,* 1948.)

"A Note on the Determination of Moisture in Producer Gas," by J. Pearson and R. Toye. (*August,* 1948.)

Afternoon Session

"Fatigue Tests on Crankshaft Steels," by P. H. Frith. (*August,* 1948.)

"A Magnetic Study of Stainless Steel Wires," by P. T. Hobson, E. S. Chatt, and W. P. Osmond. (*June,* 1948.)

"The Inter-Relation of Hardenability and Isothermal Transformation Data," by W. I. Pumphrey and F. W. Jones. (*June,* 1948.)

The discussions on these papers will be printed in later issues of the Journal.

CORRIGENDUM

Mechanical Properties of a Ni–Cr–Mo Steel

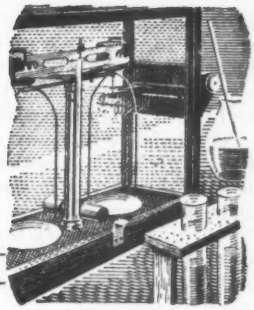
In the inscription to Fig. 4 of the paper on "*The Mechanical Properties of a Nickel-Chromium-Molybdenum Steel Obtained by Stepped Quenching,*" by G. Delbart and R. Potaszkin (*Journal of The Iron and Steel Institute,* 1947, vol. 157, Dec., pp. 527–535), the structure is said to be 'granular martensite,' whilst in the text (page 529, left-hand column, lines 17–18) it is described as 'granular pearlite.' In both cases the original French word was 'granulite,' and the error occurred in translation.

The authors state that 'granulite' is a form of pearlitic structure. The products of decomposition of austenite in the upper range of isothermal transformation are generally described as lamellar. Lowering of the transformation temperature affects the structure of the growing pearlite in two ways: It becomes finer and finer, and its contour becomes more irregular. In some alloy steels (especially Ni–Cr or Cr–V steels) with a wide region of stable austenite between Ar′ and Ar″, the lower part of the pearlite region shows granular (not lamellar) nodules which the microscope cannot resolve; these are called 'granulite,' and Fig. 4, is a typical illustration of such a structure (which is either nodular or arborescent).

The structure has been defined by H. Jolivet (*Journal of The Iron and Steel Institute,* 1939, No. II, pp. 95P–114P) and was called 'granular structure.' Later he applied the name 'granulite' to the same structure in a paper on "*The Nomenclature of the Decomposition Products of Austenite*" (*Bulletin du Cercle d'Etudes des Métaux,* 1942, vol. 3, No. 8, Dec., pp. 241–263).

B. I. S. R. A.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION



Present Methods of Open-Hearth Furnace Charging

By E. L. Diamond, M.Sc. (Eng.), M.I.Mech.E., and A. M. Frankau, M.A.

SYNOPSIS

The present methods of supplying material to open-hearth furnaces have approached their limits, whereas chargers, if not required to charge more than one furnace at a time, have a good margin above the capacity to melt, of all but the very largest furnaces. The fixed charger has a net advantage in speed over the rotating type of only about 20%, because it is interrupted when empty trains of scrap bogies are replaced. To obtain the shortest melting time it is preferable to charge at a steady rate, and therefore to have as many chargers as the maximum number of furnaces to be charged simultaneously at the maximum rate of charging. If this is taken to be half the number of furnaces installed, the theoretical loss of output is negligible and is offset by other limitations.

From this starting point, the capacities of bench loading and stage railway supply systems have been analysed on the basis of furnace frontage and capacity, using data obtained from extensive time studies. If the magnet cranes could be relieved of the duty of replacing empty pans by full pans the bench system would have ample capacity for any melting shop at present contemplated. Suggestions to this end are put forward. Stage railway systems are limited by congestion and by mutual interference of train movements, and detailed study of the working of such systems, both in practice and by charts and models, suggests that centralized traffic control on the lines indicated will be essential to attain the full capacity of such systems for very large shops. The delivery of raw materials by conveyor and bunker increases the capacity of both systems, but especially that of stage railway systems, on account of the disproportionate amount of shunting involved in feeding the raw materials to the chargers in the right sequence.

Introduction

About a third of the working time of an open-hearth furnace is occupied in charging the materials with which the steel is made ; any faults in the system by which the material is supplied and charged, resulting in unnecessary prolongation of this time, therefore, directly cause loss of production. Conversely, it is widely held that a reduction in the time of charging is the most effective way of increasing the production of an open-hearth furnace, because the charging and tap-to-tap times of groups of furnaces generally show a strong correlation.

Speed of charging may be limited by conditions in the furnace itself. The volume of an open-hearth furnace is insufficient to contain more than a portion of the charge in the form of cold scrap metal within the normal range of density, and the rate of heat input is limited by the permissible roof temperature. The charging of scrap must therefore be spread over a period of time, and the requirement governing the charging and supply equipment is that the complete charge can always be supplied at a rate which will give the quickest total melting time.

A single charging machine working without interruption can generally load scrap into a furnace at a quicker rate than it can be melted ; and with scrap of average bulk density the available volume of the furnace can be filled by the charger sufficiently quickly to necessitate intervals in the charging process during which the softening mass of scrap sags into a more compact heap and leaves room for fresh additions. The correlation between charging and tap-to-tap times arises from the fact that the rate at which a furnace can melt scrap governs the rate at which it can accommodate the successive portions of the scrap charge ; and it is in itself no proof that any advantage is to be gained by increasing the speed of the charging machinery.

Owing to its intractable nature no method of handling scrap in bulk has yet been developed. The general practice is to load it by magnet cranes into narrow pans about 6 ft. in length. These have then

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Mr. Diamond and Mr. Frankau are on the staff of the British Iron and Steel Research Association.

to be placed in a suitable position for the ram of the charger to pick them up one at a time. In existing plants the problem centres on the line of supply to the magnet cranes and between the magnet cranes and the chargers, especially the latter.

The liability of many existing plants to delay in the supply line has caused particular attention to be paid to this matter in the layout of the new melting shops under construction or projected. This has been all the more necessary because the new furnaces will be of larger capacity without a proportionate increase in frontage for the accommodation of loaded pans in place for charging.

The necessity, by present methods, of supplying scrap in such small and shallow containers, which must not be piled on top of one another, is the dominant factor in the problem. To provide room for an adequate reserve of scrap behind the chargers involves the use of a floor area at least of the same order of magnitude as that occupied by the furnace itself; if the pans stand on railway cars the area required may be several times that of the furnace for a complete charge. The standing position of a large proportion of the pans must be changed during the process of charging, as the charger cannot pick up pans from more than one row on either side of it; this complicates the already onerous task of replacing the empty pans by full pans for further charges. Apart from the question of space, considerable ingenuity is required to lay out such systems that will allow free circulation of the scrap pans, particularly for groups of high-capacity furnaces taking a substantial proportion of bought scrap.

Existing systems of supplying scrap fall into two classes: (1) Those in which the scrap is loaded into the pans in a separate scrap bay and transferred on small railway cars or bogies to the furnace stage (called hereafter 'stage railway systems'); and (2) those in which the scrap is loaded by magnet cranes immediately behind the furnace stage and placed in position for the chargers by the cranes (called hereafter 'bench systems'). There has been considerable controversy as to which is the better system. Modern examples of both are to be found in this country, and detailed analyses of some existing plants suggest that the incidence of delay depends more on the details of the layout of either system than on which system is used. That is not necessarily true for the new high-production shops, where either system will have to be developed to something like its practical limit to ensure an unfailing flow of scrap at periods of the most intensive charging.

The initiative in this matter was stimulated by a large model of the new Abbey Works of the Steel Company of Wales, Ltd. The purpose of this model was to enable the flow of materials to be studied, and in this respect it was a working model on which the quantities and rates of movement of the materials could be correctly represented. This was the starting point of the work described in the present report which was extended to embrace the quantitative factors governing both systems. It is hoped that it will not only form a basis for the design and operation of both systems, but also enable a correct decision to be made as to which type of supply system should be used for any particular works. Both main systems in their present forms are shown to have grave limitations, and it is believed that during the course of the work described, a good deal of light has been thrown on the lines on which the problem of increasing scrap-handling capacity in the future can best be tackled.

FACTORS IN THE PERFORMANCE OF EXISTING SYSTEMS

An important part of the work outlined in this report was a series of detailed time studies at a number of existing melting shops representative of the two main supply systems and their principal variants. The object of these time studies was to obtain intimate knowledge of the actual working of these systems and to compile quantitative data for the individual operations of which such systems are built up. The basic information so obtained will be summarized under subheadings representing the various elements into which all existing systems may be analysed.

Preparation of Materials

Crushing of raw materials, such as limestone, presents no difficulty as far as capacity of the crushing plant is concerned, as the quantities are relatively small. There must be sufficient storage capacity for the crushed material so as to allow for fluctuations in the rate of supply required for the furnaces, and the situation of this storage should be determined solely in relation to the layout of the supply system. These conditions are usually, though not always, met in existing plants.

The preparation of bought scrap, on the other hand, is a major factor in the supply problem as a whole, and on it depends largely the possibility of developing new methods. It has two aspects: The first, which is of principal importance for existing systems, relates to the bulk density and hence to the average weight that can be loaded into each pan; the second is the possibility of developing the technique of the preparation of scrap sufficiently to enable it to be handled in bulk by mechanical means. The second aspect will be mainly the subject for future work.

The average weight of scrap loaded per pan depends naturally on the kind of scrap, the size of the pans, and the amount of hand labour expended on trimming the loaded pans, particularly with large pieces. Scrap is so extremely variable in its physical characteristics that it is difficult to relate closely average pan weights and pan sizes, particularly as the methods of classifying scrap vary from one works to another. The data obtained from actual operation may be very roughly summarized as follows:

Average Weight (in tons) of Contents of Charging Pans at Several Works

Approx. Vol. of Pans, cu. ft.	Type of Metal				
	Light or Mixed Scrap	Pressed Bundles	Heavy Bought Scrap	Mill Scrap and Skull	Pig Iron
20	0·3–0·6	0·5	0·3–0·8	0·6–1·6	3
30	0·4–0·8	0·8	0·5–1·0	1–2	3·5

Apart from hand trimming, the only kind of preparation of bought scrap usually carried out when loading pans is the pressing of light scrap into bundles of regular shape. This gives fairly consistent weights,

which lie, however, within the range of pan weights which can be obtained with favourable kinds of mixed scrap loaded in the usual way. An important point to notice is the much heavier weights obtainable with mill scrap and broken skull. A certain proportion of this material can always be reckoned with, so that in practice the minimum average pan weights for complete charges will exceed the minimum values given above. For a works using only a small proportion of bought scrap, the high average weight of mill scrap has a considerable influence on the problem of the most suitable supply system.

Storage of Materials

The line of supply of materials can of course be traced back beyond the confines of the steelmaking plant. In this study, the source of the materials is generally considered to be the last point at which they are stored or discharged in bulk, which is also generally the point at which they are loaded into charging pans. In some cases delays are attributable to the line of supply to these storage or loading points ; this applies particularly to scrap-handling bays situated immediately behind the furnace stage. In such cases, attention has been directed to the reasons for these delays, and it has been found that they are generally due to local restrictions of layout, which can be avoided in any carefully planned new plant.

It is probable that inadequate storage space for bought scrap has in many cases been the deciding factor in favour of a stage railway system connecting the furnace stage to a scrap-handling bay separate from the melting shop, as against a bench system in which the scrap-handling bay is situated immediately behind the furnace stage. Where the movement of the scrap to the furnace stage has been regarded as a secondary consideration, it has nearly always become a major bottleneck when the capacity and number of open-hearth furnaces have been increased.

Loading into Pans

The rate at which magnet cranes load scrap into charging pans varies greatly with the nature of the scrap, but it has been found that if the rate is measured in tons per minute, so eliminating the variable factor of pan size, a good measure of agreement is obtained between average rates obtained from a number of works. Broadly, the average rates of loading continuously maintained in existing works are as given below, and as a basis for calculation an overall average rate of 0·43 tons/min. has been taken :

Average Rates of Loading Scrap into Charging Pans by Magnet Cranes

Type of Scrap	Rate, tons/min.
Light	0·14–0·2
Mixed	0·23–0·5
Heavy	0·30–0·7

Some attempt was made to find how the rate of loading differs when the magnet crane has to lift the scrap to pans at the level of the furnace stage from wagons on the ground. It appears that any such difference must be relatively small, and could only be revealed by a direct comparison with one crane loading similar scrap in the two positions. This is readily understandable when it is realized that a certain amount of long travel, as well as cross travel, is done by the magnet cranes in moving from the various wagons or from the stockpile to the pans, as the lifting can be done simultaneously with the travel motions.

Weighing

In stage railway systems it is usual to weigh the material after loading into pans on the bogies, the trains of bogies passing over a weighbridge for this purpose. The time to be allowed for weighing will be dealt with when considering the average speed of movement of trains of bogies in such a system. Each bogie is allocated to a particular furnace charge at the weighbridge office, where the charge sheets are made out. The weighbridge may be situated at the scrap yard or on the furnace stage. The latter position has the advantages that changes in the charge allocations can be made more easily to meet an emergency, and also that scrap falling from the bogies before the furnace stage is reached is not weighed. The principal requirement is that the weighbridge shall be situated at a point directly on the route of all supply trains, as otherwise extra movement, with a disproportionate loss of time, is involved in weighing. This requirement is not met in all existing plants.

In systems in which the pans are placed on benches at the back of the stage, scrap is usually weighed in trucks before loading into pans. This necessitates the allocation of truck loads to furnace charges, and hence a track layout in the scrap-handling bay which enables individual trucks to be readily shunted into and out of positions opposite the furnaces to which they are allocated, is required. It is here that such systems often fail. An alternative solution is to weigh the pans after loading, as when loading from a stockpile ; this avoids errors due to spillage during loading. In some systems mill scrap is loaded directly into pans on bogies at source and brought into the scrap bay over a weighbridge. If the charge weight is made up as the pans are deposited on the bench these bogies can also be treated as a common source ; such a system is contemplated for one new melting shop.

The raw materials (limestone, ore, etc.) are weighed in the same manner as the scrap when they are supplied on bogies in a stage railway system. There is a tendency to deal with the raw materials in this way even in new plants, so as to facilitate metallurgical control of the charge. From the economic point of view it is difficult to justify such a method of dealing with materials that can be handled with ease in conveyor and bunker systems. It is not at present the practice to weigh pans of limestone or ore filled from bunkers on the stage, as the density of these materials does not vary greatly, nor would it seem to be necessary if the pans are always filled to the top. Lack of control mainly arises from the changing of shifts in the course of a charge and the consequent uncertainty or dispute as to the number of pans filled and charged by each shift. The provision of suitable recording or weighing mechanisms presents no serious difficulty and as, even without them, experience of the use of bunkers fed by conveyor in works making a variety of steels is entirely satisfactory, it is considered that the requirements of metallurgical control

can be fully met when the raw materials are supplied in bulk to the furnace stage.

Transfer of Materials to Chargers

The method of transfer of the materials to the chargers is the principal difference between stage railway systems and bench systems. Except in cases where a melting shop is built on sloping ground, the materials must be lifted through a height of some 20 ft. from ground level to stage level. This is really the only essential movement between loading point and stage. Horizontal movement from a distant scrap bay cannot be regarded as merely an extension of the supply line to the scrap bay, even if it should lie in the direct route, because separate motive power is required and the ratio of useful weight to dead weight is greatly reduced. The movement of the pans back and fore is in itself a considerable addition to the work to be done, at any rate in the case of bought scrap.

As has been mentioned, in one form of bench system this lift is combined with the loading operation. If it were not that the loading of scrap as at present carried out is such an unavoidably untidy operation, this would be the best and quickest method, though where the charge is large it is usually impossible to accommodate sufficient of it on the stage.

In stage railway systems the lift may be accomplished either by an inclined ramp, or, if the railway is built throughout at high level, by the magnet cranes in the scrap bay or yard. With both systems another method is to raise the material by a ramp in the bulk supply line to the scrap bay and also, possibly, to the raw-materials bay. It may be noted here that for a ramp of any practicable length, approximately double the locomotive power is required to deal with the bulk materials in this way*; but this method avoids lifting the excessive proportion of dead weight represented by charging bogies and pans, at the expense of extra capital cost in constructing the stage railway. It also possesses the important advantage that the magnet cranes can be at the least possible height above the wagons, so facilitating control and reducing the heavy cost of wagon damage usually incurred in this operation.

The extra time to move an individual pan between stage and loading point in a stage railway system can be compensated by providing sufficient charge-holding tracks at the stage and an adequate number of pans and bogies. These requirements are seldom met in existing stage railway systems. In existing works the overall average speed of movement of trains of bogies between the loading point and the point of arrival at the melting shop is about 3 m.p.h. without weighing, and under 2½ m.p.h. including weighing. Individual times vary greatly owing to stoppages of varying duration, particularly at points where direction is reversed, as when drawing out of a loading road on to the running track.

The bogies, besides being brought up to the stage, have to be placed in the correct position for the charger, and the empties have to be withdrawn. In this respect stage railway systems have an important advantage over bench systems. The bogies may be placed either behind or in front of the charger, which may accordingly be of the rotating or the fixed type. Most existing stage railway systems supply the charger at the rear of the stage, and there are few examples where independent charge-holding roads are provided. A single track (especially if, as in most cases, it has a dead end) provides the minimum of flexibility in replacing empty bogies by full bogies, even though the charger can itself move loaded bogies along the track to a position most convenient for charging a particular furnace. Single-track systems of this kind have in most cases become a source of delay when the capacity of the melting shops in which they were originally installed has been expanded.

A good deal of data has been gathered on the time required to shunt bogies in and out of position on the stage when charge-holding roads are provided, which can best be considered when the layout of modern stage railway systems is discussed. For the present it should be observed that to replace a run of bogies in position for the charger may take 10 to 15 min., or even longer if several furnaces are charging and the stage locomotive is not immediately available to transfer the trains to and from the adjacent turn-outs.

In bench systems the most usual practice, if the pans are not loaded directly on the stage, is for the magnet crane to lift the loaded pans, several at a time, to stage level by slings. In existing shops it takes about 5 min. for the crane to replace a batch of empty pans by a batch of loaded pans, but the methods of attaching and detaching slings are often slow and cumbersome. The total time required for this operation for a complete charge is nevertheless considerable, and must be allowed for over and above the rates given on page 193, but there is the important advantage that it does not interrupt the charger, which may continue to charge the loaded pans already on the bench. The point will be considered more fully when examining the performance limits of such systems.

Charging

Extensive data from direct observation at a number of works show a considerable degree of uniformity in the rate of operation of rotating chargers. An overall average rate of 1·2 min. per pan can be maintained throughout the charging period of a furnace and is a safe figure to take. It does not include idle times between successive runs of charge, but it will cover all the usual incidental delays during a continuous run. The actual range of average times observed was from 1 to 1·4 min. per pan, but the greater averages related to periods when there was no need for hurry.

There are at present in this country few examples of the fixed type of charger taking pans from bogies on a track immediately in front of the furnace. Of the three cases studied, two charged at a slower average rate than the rotating charger, whilst the third attained an average rate of 0·54 min. per pan. This method has been adopted for certain new plants because the elimination of the rotating movement should enable the charger to operate at about twice

* *Journal of The Iron and Steel Institute*, 1948, vol. 159, May, p. 45.

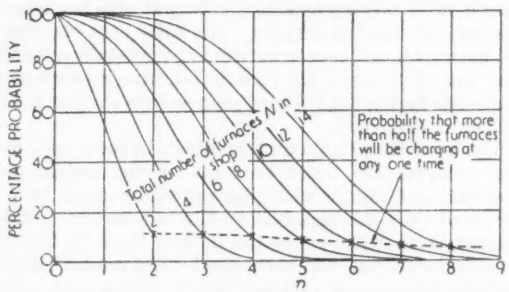


Fig. 1—Probabilty of *n* or more furnaces charging at any one time. Charging time one-third tap-to-tap time

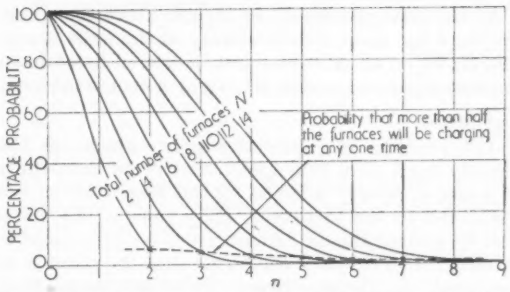


Fig. 2—Probability of *n* or more furnaces charging at any one time. Charging time one-quarter tap-to-tap time

the speed of the rotating charger, and the third example mentioned above proves that this can be done. Of the other two cases, one is an old shop where the clearance is insufficient to allow the charger to operate over the bogies, and the other is a modern shop where the charger is of very heavy construction and the travelling movements are somewhat sluggish. In neither case is a faster rate of charging required, nor for that matter is it a necessity in the shop with the very fast chargers, where, in consequence, long intervals usually occur between successive runs.

Number of Chargers Required

An all-important question is the number of chargers in relation to the number of furnaces, but there is some variation of practice in this respect. In most melting shops the proportion of chargers to furnaces is not less than 1 : 2, but in some cases fewer chargers are available. One exceptional case is the melting shop already mentioned with the very fast-working fixed chargers. The furnaces are somewhat slow working and it was obviously the intention that one charger should be able to charge two furnaces simultaneously, and in fact this can be carried out satisfactorily.

General practice is, in effect, to provide a separate charger for as many furnaces as are likely to require charging simultaneously. Expressed in this way, this rule requires some explanation. It could sometimes happen, particularly when working ceases over the week-end, that all the furnaces require to be charged simultaneously. But that would mean that all the furnaces must be tapped within a short period. It would be uneconomical, even if it were practicable, to provide equipment for tapping all the furnaces together, and in any case this would result in extreme fluctuations in the flow of hot ingots to the soaking pits and the mills. In absolutely regular working, one-third of the furnaces would be charging at any moment. It is obviously impossible to maintain a regular cycle, and if loss of output is to be avoided a certain measure of ' bunching ' of the furnaces must not cause delay in charging. So many complex factors are involved that the matter is best settled by general experience. On this basis it is considered that this requirement is adequately met if half the furnaces can each be simultaneously charged by a separate charger.

The theoretical loss of output incurred by not being able to charge more than half the furnaces simultaneously may be estimated by the theory of probabilities. The problem is greatly simplified by assuming a uniform tap-to-tap time and a charging time equal to a fixed fraction of the tap-to-tap time. In the average, the results will not be affected by these assumptions. The results depend very largely on what fraction is assumed for the charging time, and the problem has been worked out for the two cases when the average charging time is equal to one-third and one-quarter of the average tap-to-tap time respectively.

If there are N furnaces, the probability that n of the furnaces will be charging together at any moment for a charging time of one-third the tap-to-tap time, is given by :

$$(1 - \tfrac{1}{3})^{N-n} \times (\tfrac{1}{3})^{n} \times {}^{N}C_{n}$$

and for a charging time of one-quarter the tap-to-tap time, by :

$$(1 - \tfrac{1}{4})^{N-n} \times (\tfrac{1}{4})^{n} \times {}^{N}C_{n}$$

These expressions have been evaluated for 4, 6, 8, 10, 12, and 14 furnaces, and the integrated probability of more than a given number of furnaces charging at any one time is plotted for the two cases in Figs. 1 and 2. The percentage of time theoretically lost by not being able to charge more than half the furnaces at one time is as follows :

Theoretical Percentages of Time Lost with Half as many Chargers as Furnaces

Number of Furnaces	Ratio of Charging Time to Tap-to-Tap Time 1:3	1:4
4	12·3	5·5
6	12·1	4·3
8	11·0	3·2
10	10·0	2·4
12	8·9	1·7
14	8·0	1·4

It will be shown later that if the chargers work continuously at one furnace very short charging times are possible. If charging takes the more normal ratio of one-third the tap-to-tap time there will be intervals when one charger can work on another furnace. The figures for a ratio of one-quarter may therefore be taken as a correct approximation, and it will be seen that, apart from the avoidance of excessive ' bunching ' of the furnaces, the possible loss of time in the larger shops by having half as many chargers as furnaces is generally considerably less than 5%, especially having in mind that one furnace is generally under repair.

All the chargers should be able to move the whole length of the shop, independently of the ladle crane. The provision of extra chargers in case of breakdown requires separate consideration which is omitted here.

Hot Metal

The problem of material supply, which, as has already been seen, principally centres on the supply of scrap, is greatly affected by the proportion of hot metal fed to the furnaces. Fifty tons of hot metal can be poured into a furnace from a single ladle in 4 to 5 min. Provided, therefore, that the plant is so arranged that the movement of the hot metal from the mixers to any furnace does not clash with any other operation, delays in the supply of hot metal can easily be avoided. This unfortunately is not always the case in existing shops. Where the hot metal is poured in on the pit side, delay is always liable to arise from furnaces tapping in the line of approach from the mixer. On all modern plants the hot metal is therefore added on the stage side. When this is done it is generally inconvenient to handle the ladle of hot metal throughout by the crane. If the metal is tapped on the pit side it must be transferred by car to a suitable position under the stage, whence it can be lifted up by the crane. In some modern plants the hot metal will be tapped at stage level and moved opposite the furnace to be charged by a transfer car at the back of the stage. In either case the crane must be able to pass over the chargers when loaded with a ladle of metal.

CHARGING REQUIREMENTS

Before considering the limitations of charging machinery and supply systems in relation to the demands of modern open-hearth plants, it is necessary to know not only the minimum time in which the furnace can accept the charge, but also how the charge should be distributed over that period in order to secure minimum melting time. So much emphasis is frequently placed on the need for greater rates of charging that it appears to be widely believed that charging should take place at the highest attainable rate, even if comparatively long intervals must be left before the furnace can assimilate successive runs of charged material.

The problem has been approached both by practical observation of furnaces in production and by theoretical analysis. For the latter, the assistance of the Physics Department of the British Iron and Steel Research Association was sought, and their investigations are the subject of a separate paper.* Their main conclusions are incorporated in the following account of the problem, for they are fully in accord with the view arrived at from practical observation.

The rate of heating, and consequently the rate of melting, depends primarily on the temperature difference between a piece of metal and its surroundings. Thus, in an open-hearth furnace the rate of heating is at a maximum when the roof and flame temperatures are at a maximum and the surface of the charge is cold. Also, if the material below the surface of the charge is at a lower temperature than the surface, reradiation from the surface is higher than it need be and heat has to be put into the mass against a thermal resistance. The total heat entering the bath is the difference between the gross downward heat flow on to it and the reradiation from its surface ; hence the higher the surface temperature the less heat will enter the bath.

There are thus two requirements to be met : (*a*) The roof temperature must be kept at the maximum possible, and (*b*) the charging procedure must be so arranged that the material on the top surface is the coldest, so that it absorbs the bulk of the heat before it is conducted into the bath. Both these requirements exclude a charging method which causes any considerable drop in roof temperature, that is, a method in which large quantities of material are put rapidly into the furnace.

Figure 3 is an actual record of a charging procedure, showing the roof temperature and heat input as well as the additions of material, on a time base. It can be seen from this that even the smallest batch charged has caused an appreciable drop in the roof temperature, and also that if periods between batches, or 'runs,' are too long, the rate of heat input must be reduced to prevent overheating of the roof. This in itself is an indication that the rate of heat transfer to the charge has dropped to a value too low to enable the full heating capacity of the flame to be used. It is therefore concluded that the ideal procedure is to charge continuously and uniformly at such a rate as to keep the roof temperature just at its maximum while the maximum rate of fuel input is maintained.

Experiments were carried out in the Physics Department by melting paraffin wax in a simple model representing an open-hearth furnace. These showed that the length of time the charge is in the furnace has no direct connection with the melting time. For a given flame radiation the melting time can be reduced only by reduction of the time average of the reradiation from the surface of the charge, and since the charge as a whole must increase in temperature during melting, this time average cannot be reduced below a certain minimum. This minimum clearly occurs in the case where the temperature of the top surface of the material in the furnace is below or equal to that of the material lower down, all the time until melting is complete.

The opening of the furnace doors during charging is a factor that should be mentioned. In practice it is usual to open and close the door immediately before and after each pan is actually inserted in the furnace, and there is no increase in the total time during which

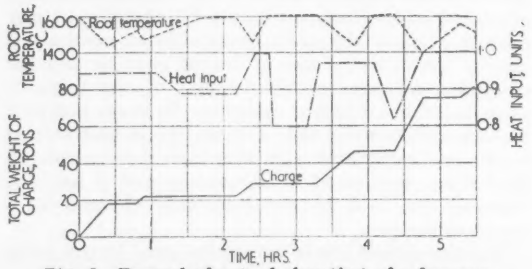


Fig. 3—Record of actual charging of a furnace

* *See* pp. 212–221 of this issue.

Table I

OBSERVED CHARGING SEQUENCES FOR VARIOUS HOT-METAL SHOPS

Charging Sequence No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Nominal furnace capacity, tons	65	80	95	95	95	95	120	120	180	200*	200*	200*	250*	250*	250*
Hot metal (in metallic charge), %		45·5	55	64	53	74				66	78·5	65·5	63	75	65·5
Total cold charge, tons		72·7	48·8	41·8	50·0	31·0	49·2	48·1	35·2	145·6	69·6	116·2	140·3	93·1	91
Average pan weight, tons:															
Scrap only		1·11	0·564	0·383		0·595	0·391	0·521	Nil	0·92	0·65	1·1	0·785	1·17	0·745
Overall		1·15	0·582	0·414	0·926	0·633	0·475	0·641	0·98	1·18	0·904	1·20	1·05	1·58	0·62
Overall charging rate:															
Cold charge, tons/min.		0·373	0·254	0·260	0·532	0·365	0·246	0·236	0·193	0·59	0·20	0·587	0·405	0·52	0·451
Cold charge pans/min.	0·214	0·323	0·438	0·644	0·575	0·577	0·448	0·368	0·197	0·445	0·221	0·49	0·383	0·330	0·597
Charger operating rate:															
Tons/min.		0·817	0·568	0·383	1·02	0·681	0·428	0·364	0·326	1·09	0·74	0·96	0·762	0·755	0·660
Pans/min.	0·813	0·709	0·980	0·926	1·10	1·07	0·775	0·568	0·333	0·917	0·820	0·80	0·725	0·478	0·877
Percentage of charging period that charger is in operation (excluding hot-metal additions)	26·4	45·6	45·3	69·5	50	54·1	57·2	64·7	59·0	48·4	26·3	60·6	48·8	68·7	71·9

* Tilting furnace

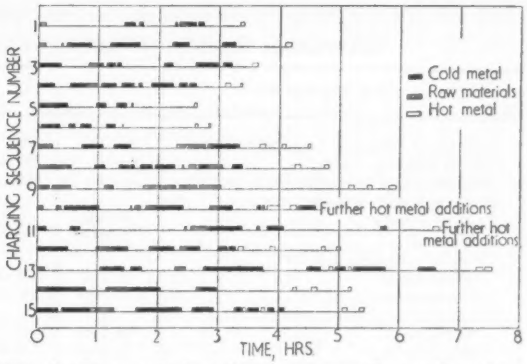


Fig. 4—Observed charging sequences for various hot-metal shops

the doors are open as between a rotating charger charging one pan per minute and a fixed charger charging two pans per minute.

CHARGER PERFORMANCE LIMITS

Charger Performance in Practice

The preceding section will have made it clear that there is a definite limit to the rate at which it is advantageous to charge a furnace, and also that this limit is dependent entirely on factors associated with the furnace itself, its dimensions, and its rate of heat input. That this is so in practice is shown by Figs. 4 and 5 and by Tables I and II, in which the details of 22 charges of separate furnaces in a wide variety of melting shops are recorded on a time base. In no case was the charger required to operate continuously. Many instances of delay in charging have been observed (but not in the charges recorded in Figs. 4 and 5); but no case has come under the notice of the investigators of delay being due to the inability of an individual charger to put the charge in as fast as an individual furnace could accommodate it. The main causes of delay are, first, interruption of the supply of material to the charger; and, second, occupation of the charger on other duties. The first of these will be the subject of the next section. The second is a question of the proportion of chargers to furnaces, and delays due to this cause are found to arise mainly in shops with more than two furnaces for every one charger, or where a charger is defective and out of action.

If the number of chargers is less than the maximum number of furnaces to be charged simultaneously at the full rate (which it has been suggested should be not less than half the total number of furnaces in the shop), then of course the rate of operation of the

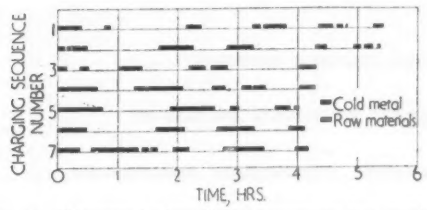


Fig. 5—Observed charging sequences for various cold-metal shops

Table II

OBSERVED CHARGING SEQUENCES FOR VARIOUS COLD-METAL SHOPS

Charging Sequence No.:	1	2	3	4	5	6	7
Nominal furnace capacity, tons	90	90	90	95	95	100	100
Total charge, tons	83·7	89·6	84·1	92·5	93·4	103	102
Pig iron (in metallic charge), %	36·5	34	35·5	25	32	27·5	27·5
Average pan weight, tons:							
Scrap only	0·606	0·622	1·19	0·65	0·847	0·82	0·632
Overall	0·855	0·860	1·15	0·805	1·09	0·962	0·790
Overall charging rate:							
Tons/min.	0·257	0·278	0·321	0·358	0·388	0·417	0·405
Pans/min.	0·300	0·322	0·279	0·445	0·357	0·433	0·514
Charger operating rate:							
Tons/min.	0·796	0·785	0·99	0·670	0·805	0·792	0·675
Pans/min.	0·935	0·909	0·860	0·833	0·741	0·820	0·855
Percentage of charging period that charger is in operation	32·2	35·3	32·4	53·5	48·1	52·6	60·1

charger must have a correspondingly greater margin over the maximum rate at which the furnace can accept the charge. The considerations advanced in the preceding section suggest that the method of dividing the operation of a fast-working charger between two furnaces will not give the best melting rate in either. There is another practical objection to it in that the successive runs of charge must alternate between the two furnaces and that if one furnace is not ready to receive its next run when the charger arrives, this may cause delay to the other furnace. There is also the possibility of delay in moving the charger from one furnace to another. General practice has shown that the suggested rule of one charger for every two furnaces is not extravagant.

That there must be some margin between the capacity of the charger and the capacity of the furnace to accept the charge is obvious. Time must be allowed for observation and control of the furnace. Generally, however, the margin in existing practice is much greater than is necessary for this purpose, as will be seen from Tables I and II. The maximum proportion of the cold-charge period during which the charger was actually in operation in any of the observed charging sequences was 72%, and the margin of 30% was more than sufficient for other duties. The margin for any particular furnace and charger is shown to vary greatly in practice with variations in the average pan weights, and in planning a new melting shop it is necessary to consider the lowest average pan weight for a complete charge

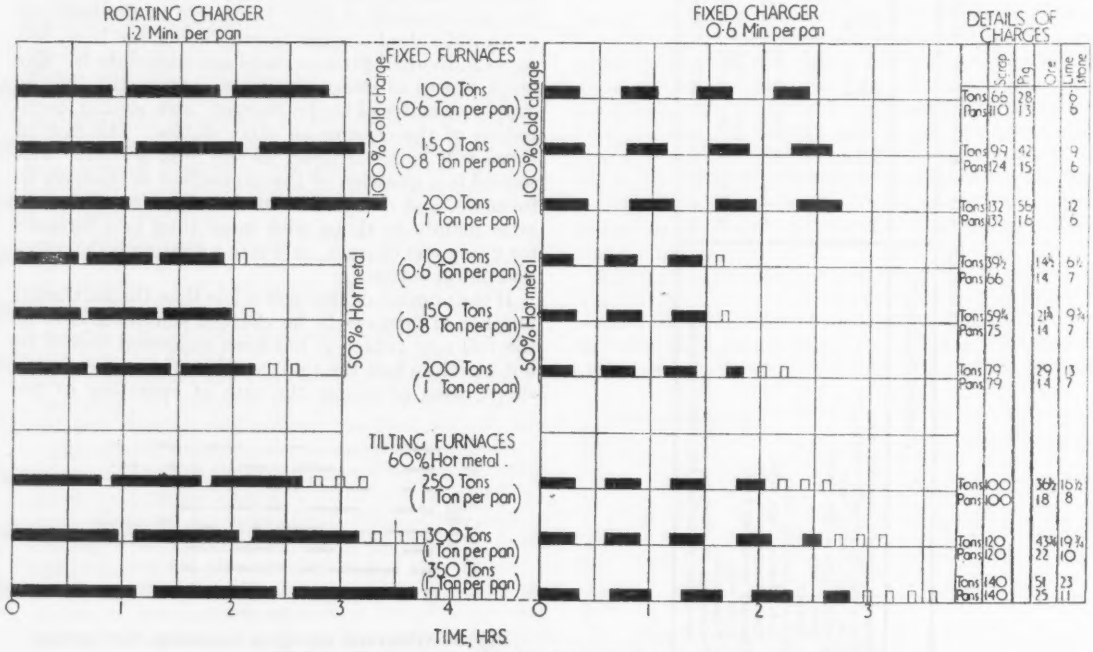


Fig. 6—Performance limits for rotating and fixed chargers

likely to occur in normal working, and to allow a minimum margin of 10% on the actual charger operating time.

Performance of the Fixed Charger

A further consideration affects the fixed charger taking pans off bogies at the front of the furnace stage. As has been mentioned, it will be shown that at times when several furnaces are charging it takes from 10 to 15 min. to replace a rake of bogies from the charge-holding roads. Every time this has to be done the charger must perforce cease charging. Thus, the fact that the fixed charger may work twice as fast as the rotating charger is offset to some extent by this lost time, which is really equivalent in its cause to the time taken by the rotating charger to transfer pans to and from the back of the stage. In a typical case the total time accountable to this cause, neglecting any movements before charging actually begins, but including the time to remove the last empty rake before adding the hot metal, would not be less than $\frac{3}{4}$ hr. per charge in the most favourable circumstances, and where runs have to be divided when adjacent furnaces are charging, this might be increased to $1\frac{1}{2}$ hr. These figures assume that the stage locomotive is immediately available when required to transfer the trains to and from the adjacent turn-outs. The 10% margin on the charger operating time will still be required as a minimum to cover the occasions when this is not so.

Performance Limits of Rotating and Fixed Chargers

From the basic data so far reviewed, Fig. 6 has been prepared to show the limits to the performance of chargers of the existing types for a range of modern open-hearth furnaces, and pan sizes and weights appropriate to each size of furnace. (Data relating to scrap pans for furnaces of different capacities, which have been taken as an appropriate basis for the calculation of the curves in this and subsequent graphs, are shown in Fig. 7.) It should be emphasized that these performance limits are based on overall averages with existing chargers, and are in that sense conservative, but realistic. A time as low as 42 sec. per cycle has been guaranteed for the rotating chargers for one new melting shop, and no doubt this can be attained on test. But all sorts of minor incidents, such as the falling of large pieces of scrap in the doorway, are unavoidable in practice, and the performances represented in Fig. 6 allow for all but exceptional contingencies.

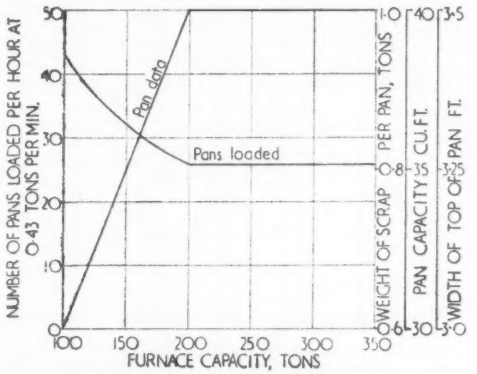


Fig. 7—Data relating to scrap pans

It is not within the scope of this report to estimate the minimum times in which modern furnaces can accept their charges, but on the basis of the requirements specified for the new melting shops now in course of planning or construction, these performance limits give a good margin over the limits of the furnace capacity in nearly all cases, and it is particularly to be noted that the contention that it is essential to use fixed chargers, and hence stage railway systems, for most modern plants, cannot be supported on these grounds. On the other hand, the fixed charger can undoubtedly complete the charge in a shorter time, and therefore has a greater margin for contingencies, though at the expense of less even distribution of the charge over the charging period. Consideration of the two systems for any particular shop must take into account the supply system since, as has already been mentioned, the fixed charger necessitates a stage railway system.

SUPPLY-SYSTEM LIMITS

Charge-Holding Capacity

As mentioned previously, the basic difficulty in supplying the chargers regularly is the extravagant requirements of floor space by scrap metal loaded in charging pans. Whether fixed or rotating chargers are used, only one row of loaded pans can be placed initially in position for the charger to pick them up. This row will be limited in length by the distance between furnace centres. In the case of a bench, the net length available must allow for the control cabin and any structural stanchions. Raw-material bunkers will entail only a partial restriction of length, since a filled pan can stand underneath each chute. In the case of bogies the space between eacn bogie must be allowed for.

The difficulty of providing adequate supply systems has disproportionately increased as the capacity of furnaces has grown, because the growth of furnace capacity is largely the result of improvements in design, and has not been accompanied by a corresponding increase in length. The whole position is summarized in Fig. 8, which shows the number of loaded pans that can be placed in position for each system, compared with the total number required for a complete charge, on the basis of furnace frontage.* The distance between centres of furnaces of a given capacity varies a good deal in different shops, and the graphs representing furnace capacity and number of pans required, in Fig. 8, are therefore in the form of bands covering the normal range of variation. It might well be that it would be economically justifiable in a new shop to space the furnaces at wider intervals solely to ease the material-supply problem. In that case, Fig. 8 affords a ready means of assessing the gain to be secured in this way.

It will be seen that in modern shops the first row of loaded pans must be replaced several times during the course of the charge. (It was pointed out in the previous section that an important difference between

* The term 'frontage' is to be understood as the distance between the centres of adjacent furnaces.

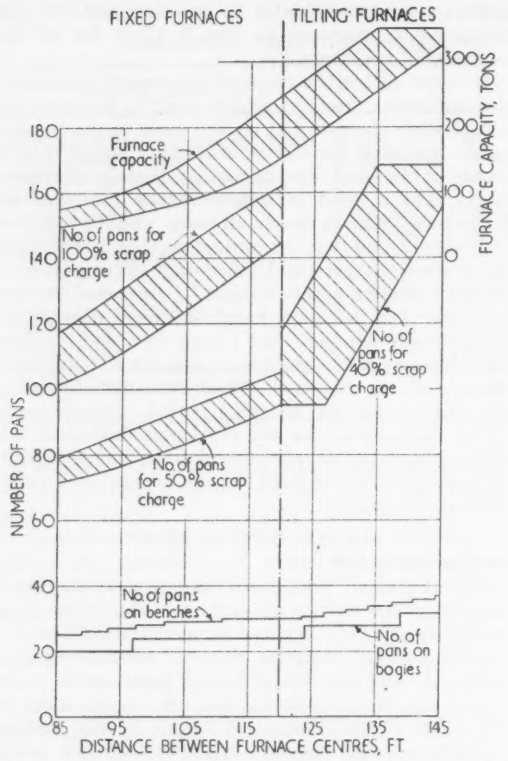


Fig. 8—Number of pans that can be held, compared with number required for a complete charge

the fixed and the rotating charger is that the former is put out of action while replacement takes place, whilst the latter can continue to charge.) The question that next arises is : What is the total number of loaded pans that must be available in the charge-holding roads, or immediately behind the benches, to meet the greatest demand ? Here, again, we start from the basic rule that half the total number of furnaces (equal to the total number of chargers) is the maximum number of furnaces required to be charged at the full rate simultaneously. It follows that rather less than double the furnace-centre distance is available for charge-holding tracks on supplementary benches. In order to hold a complete charge in readiness for every charger, therefore, there would have to be 2 or 3 charge-holding tracks running the full length of the shop, or 1 or 2 lines of pans ready for lifting to the benches in the scrap-loading bay. (Note that the furnace line, unlike the benches on the stage, cannot be included in the charge-holding capacity since it may not be occupied until charging is due to commence.)

During charging, scrap loading continues, and in stage railway systems trains of loaded bogies continue to be brought into the shop, as soon as charge-holding tracks are vacated. On the other hand, it would not do to allow the stock position to fall to zero at the end of the intensive charging period, as one or more additional furnaces may then be ready for charging. It is reasonable to assume that the most extreme requirements would be met if sufficient stock were available at the end of a period of maximum ' bunching ' to provide complete charges for one-third of the remainder of the furnaces in the shop. It remains, therefore, to ascertain what proportion of each charge can be replaced by the supply system during the charging period. If it is less than one-third of the charge, the supply system is inadequate and delays will result.

Bench System

It is fairly obvious that if a bench system is not to be unnecessarily limited in capacity there must be at least one magnet crane for every charger, and this is the rule in practice. As an overall rate of loading, a figure of 0·43 ton/min. has been selected as a safe average figure for the usual composite charges (*see* page 193). Figure 7 shows the number of pans of scrap that can be loaded per hour for the range of pan capacities used throughout these calculations (giving 0·6, 0·8, and 1 ton of scrap per pan). In any modern bench system the raw materials would be loaded from bunkers and would occupy the magnet cranes, if at all, only for the time required to lift the raw materials to the bench on the stage.

In a modern shop, with furnaces of high capacity, it would be desirable to improve on the method of slinging pans by hand to chains attached to the magnet cranes. With this method it takes about 5 min. to complete a round lift (*i.e.*, slinging and lowering three empty pans and slinging, lifting, and depositing the same nu ber of full pans). Trays to

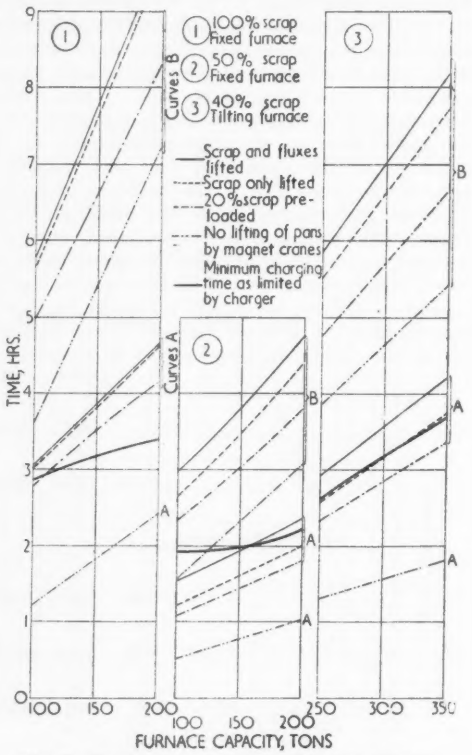


Fig. 9—Performance limits of bench system

lift as many as five pans at a time are in use in some shops. In a new shop to be constructed, the pans will be lifted three at a time without a tray, the magnet carrying two pivoted arms like a grab, which the crane driver can lower under the ends of the pans. By eliminating the need for any attachment the time for a round lift is expected to be reduced to well below 3 min. To allow 1 min. per pan for replacement would keep the calculated performance limits of the system within the range of the known performance of existing types of machinery.

Figure 9 shows the overall limits of the supply system for both cold- and hot-metal shops. The results are presented in two sets of curves *A* and *B*. The lower set (curves *A*) show the minimum time in which the required condition (that one-third of a complete charge should be replaced) can be met. The upper set (curves *B*) show the total time required to prepare a complete charge. The full-line curves apply when the raw-material bunkers are at ground level and the pans have to be lifted to the stage by the magnet cranes ; the dotted curves apply where the raw materials can be delivered by conveyors to bunkers at stage level ; and the chain-dotted curves apply when 20% of the metallic charge is mill scrap loaded into pans at source, and therefore requires lifting only. The replacement charges are, as explained, assumed to be distributed between one-third of the remaining furnaces in the shop (*i.e.*, one-sixth of the total number of furnaces), and the number to be lifted to the benches is calculated accordingly.

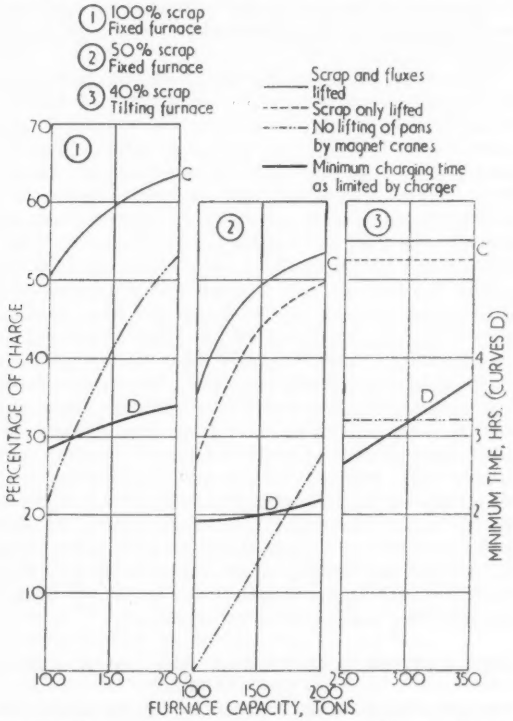

1 100% scrap Fixed furnace
2 50% scrap Fixed furnace
3 40% scrap Tilting furnace
Scrap and fluxes lifted
Scrap only lifted
No lifting of pans by magnet cranes
Minimum charging time as limited by charger
PERCENTAGE OF CHARGE
MINIMUM TIME, HRS. (CURVES D)
FURNACE CAPACITY, TONS
C
D

Fig. 10—Percentage of charge which must be previously prepared, to charge in minimum time. Bench system

In practice, of course, it is unlikely that loading would proceed in this manner, as it would be virtually impossible for all the cranes to concentrate lifting and loading operations at one-third of their number of benches in between lifting the already loaded pans at the furnaces under charge. A more practical way of looking at it is to consider what is the minimum proportion of the charges that must be ready beforehand to enable half the furnaces in the shop to be charged simultaneously at the maximum rate of which the chargers are capable. This is obtained directly from the ratio between the minimum time of charge, as limited by the charger, and the total time to prepare a charge ; and the result with a 10% allowance for contingencies, is plotted as a separate pair of curves *C* in Fig. 10. The minimum time of charge (as set by the charger) is also plotted in Fig. 10 (curves *D*) from the values given in Fig. 9.

Figure 9 shows clearly that for cold-metal plants, taking 100% of scrap and pig iron, the supply system is the first limitation on the rate of charging for furnace capacities greater than 100 tons. For furnaces taking 50% of hot metal, or more, the ultimate performance limits of charger and supply system show a good measure of parity over the whole range of furnace capacity. Even if it be allowed that the charger limit leaves a substantial margin on the minimum charging times likely to be required, curves *B* show that for cold-metal shops with furnaces with a capacity of 100 tons or more, additional lifting cranes would be required if all pans are loaded at ground level. Each magnet crane, in the conditions on which Fig. 9 is based, has to prepare two complete charges for every furnace cycle. Whilst a higher ratio of working time can be maintained by the magnet cranes in bench systems, as compared with stage railway systems (as pans are always available for loading), there must be some margin for contingencies ; 4–5 hr. in which to prepare a total charge therefore means the minimum margin in a shop with an average tap-to-tap time of 11 hr., and all furnaces in operation. In such cases it will make all the difference if mill scrap is loaded at source and if the raw materials can be conveyed direct to the stage.

A modification of the bench system, which would greatly extend its capacity, would be the provision of a separate mechanism for changing the pans. This is actually in operation at one cold-metal shop, where, however, the proportion of chargers and magnet cranes to furnaces is less than one for every two furnaces. In this example the lifting is done by separate mono-rail cranes, which have to be continuously manned. During lengthy periods, when only the normal proportion of furnaces are charging, the mono-rail and the magnet cranes may have to wait for each other a good deal, and the method is relatively costly.

The problem of providing an alternative arrangement is not as simple as it appears at first. Figure 11 is an outline of one suggestion which it is hoped to investigate and to develop further in the near future. By such means, as can be readily estimated from the data already presented, the capacity of the bench system could be increased beyond the maximum charging capacity of the fixed charger. The bench system, of course, is inseparable in its present form

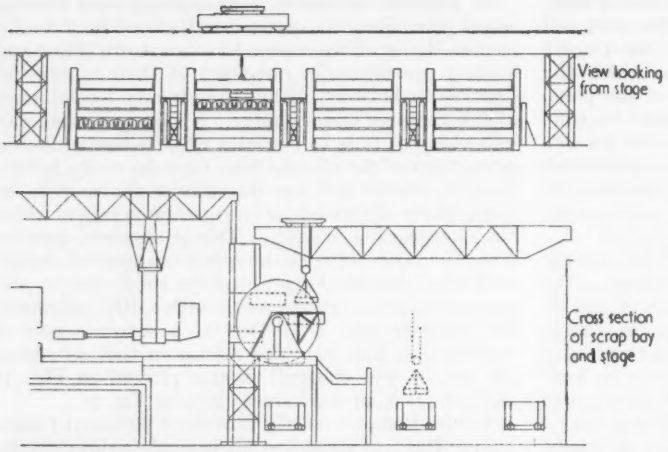


Fig. 11—Suggested high-capacity bench loading system

from the rotating charger. The point is made only because we are here concerned in finding where the ultimate limitations really lie.

An important point to notice is that the capacity of the bench system is independent of the number of furnaces in the shop. Each furnace has its own line of supply, and provided that there is always a charger and a crane for every pair of furnaces, there is no limit to the number that can be worked in this way in parallel, so long as there is adequate provision for bringing in the scrap in bulk.

Stage Railway System

The time required to move bogies into and out of position for the chargers in stage railway systems has already been taken into account in setting the limits for the fixed-charger performance. The function of the stage railway may therefore be regarded solely as the equivalent of the lifting operation in the bench system. Even if the stage railway is entirely at stage level—the actual lift taking place in the bulk supply line—this comparison holds good for the purpose of computing its capacity.

In the stage railway system the whole of the charge for half the furnaces (taking the same maximum requirements) is held in the charge-holding roads on the stage. If, at the end of the charging period, there is to be, as before, a complete charge for one-third of the remaining number of furnaces, it must be possible (assuming the minimum number of pans and bogies to meet this requirement) to return one-third of the empties to the scrap bay and raw-materials bay, reload them, and bring them up to the stage again within the minimum possible charging period. But the first rake of empty bogies is not available till the middle of the interval between the first and second runs, and the reloaded bogies must be up on the stage some fifteen minutes before the end of the charging period to allow time for the stage locomotive to shunt them into position for the next charge. If the scrap and raw-materials bays are in the nearest possible position at the entrance to the shop and at stage level, the journey there and back will take, on an average, not less than 10–15 min., including weighing. If the scrap and materials bays are at some distance and at ground level, the return journey may take up to 45 min. If, now, the charging sequences of Fig. 6 are examined in conjunction with the number of pans per charge, as given for the corresponding conditions in Fig. 8, it will be seen that, assuming again the same number of magnet cranes as chargers (one per furnace under charge), it would be impossible to circulate and reload one-third of the bogies within the minimum possible charging period for any of the conditions.

Additional bogies may, however, be held in the scrap and raw-materials bays, and this is what will be done in practice. If each magnet crane can work over one-third of the total number of scrap bogies in a charge, then the capacity of the stage railway system is about the same as that of the bench system, *relative to the maximum overall rate of the fixed charger* which, as has been shown in Fig. 6, is about 20% faster than that of the rotating charger. Indeed, these considerations lead to the conclusion that the basis of design for a stage railway system should be that the charge-holding roads should accommodate complete charges for half the furnaces, and the scrap and raw-materials bays one-third as much, the number of magnet cranes being equal to the number of chargers, as in a bench system, and the number of bogies being sufficient to fill the combined holding accommodation on the stage and in the materials bays.

There is an all-important factor which has not yet been considered. It has been assumed that all the movements of bogies necessary can be made without mutual interference. In the stage railway system there is only one route from the loading bays to the stage, and not an independent route to each furnace, as in the bench system ; and as the number of furnaces increases, so does the congestion at the entrance to, and on, the melting-shop stage. This aspect of the matter has been studied in great detail, particularly in conjunction with the model of the new melting shop at Margam, in South Wales. The results will be considered in the next section, but for the moment it should be said that the capacity of the stage railway system is stretched practically to its limit when the requirements set out in the last paragraph are complied with, and the number of furnaces exceeds eight or ten, even with the slower overall charging rates attainable in practice with existing types of furnace. All the traffic movements must be rigidly controlled, and attempts to increase the maximum capacity of the system by adding more charge-holding accommodation and bogies would probably be nullified by the resulting congestion of the system.

THE LAYOUT AND OPERATION OF A STAGE RAILWAY SYSTEM

Method of Study of the Problem by Charts and Models

When the British Iron and Steel Research Association were invited to co-operate with Messrs. Guest Keen Baldwins Iron and Steel Co., Ltd., early in 1947,

in studying the layout of a typical modern stage railway system for a large melting shop, it was intended to carry out a number of trials on the working model of Abbey Works (referred to on p. 192). Each of these trials would have to represent working periods of about 12 hr., which is equivalent to the average furnace tap-to-tap time. The model could be altered without difficulty to represent various possible arrangements of the plant and track layout.

Owing to the numerous combinations of circumstances that require study, many hours of operation of the model would have been necessary, even if the movements on the model were all made at double speed. A team of about twelve operators was required to work the model. Only a small proportion of the time of operation, however, would actually present situations taxing the capacity of the supply arrangements to the utmost. Before proceeding with experiments with the model, consideration was given to the possibility of scheduling all material loading, moving, and charging operations on charts. In this way it was thought that long periods of relatively uninteresting conditions of operation could be eliminated, and the work of the team of operators required for the model could be concentrated on the short periods of peak activity. Some scheduling of movements is necessary for the purpose of briefing the operators working the model, and a good deal of work had been done on these lines by the engineers of the International Construction Co., Ltd., responsible for the building of the new plant. In building up their schedules they used diagrams showing in coloured pencil lines the state of each furnace at any given time, and this principle was taken as the starting point in evolving the charts about to be described.

The basic idea was to have a continuous chart on a horizontal time scale divided into minutes. On this could be plotted not only the state of each furnace, but also the movements of all trains of bogies and of the locomotives (in the manner of a railway train diagram) together with the operation of the chargers and the scrap-handling cranes. The problem was to devise a form of chart that could show all these activities without confusion or any element of uncertainty. It was realized that it would be essential that such a chart should keep a tally at every moment of every bogie in circulation. This requirement can best be met by dividing the chart by horizontal lines into small squares and grids so that each horizontal grid represents a particular station at which bogies may stand, the individual squares showing that station at each minute on the time scale. The number of bogies standing at any station at any minute can then be indicated by a figure in the appropriate square, and some simple indication, such as a circle round the figure, can be used to distinguish loaded bogies from empty ones. The position and movements of trains of bogies can be shown by lines and arrows from one square to another.

The principal stations at which bogies may stand are (1) the scrap-handling bay, (2) the raw-materials bay, (3) the charge-holding roads, and (4) the furnace road.

The form of chart eventually evolved is illustrated in Fig. 15, and is divided up into grids representing these stations, there being a sufficient number of grids in each group to allow one for each length of track, with separate access, in the most complex layout likely to be met with. When a number of bogies remain at a station for a period of more than 2 min., a thick horizontal line is drawn connecting the figures showing the number of bogies at the beginning and end of the period of standing. In this manner it is possible to account for every bogie in circulation at any minute during operation.

If the movements of more than one locomotive are being studied, differentiation is obtained by using separate colours (or full and broken lines) for the lines and arrows associated with each locomotive. The movements of the locomotive by itself are shown by dotted lines and arrows, and as these movements are not related specifically to a particular furnace they may necessarily traverse the whole width of the main diagram. The times of all movements from one point to another are calculated accurately on an average speed which will depend, in individual cases, on the layout of the railway system and on the type and power of the locomotive concerned. All such motions are represented by inclined lines, whether full or dotted.

The furnace roads are shown in conjunction with the continuous record of the operation of each furnace. Thus there are two series of squares for each furnace. On one of these runs a continuous coloured line (reproduced by varied kinds of sectioning) representing the state of each furnace (charging, melting, refining, under repair, etc.), and the other represents the portion of the furnace road on which bogies stand when the charger is in operation at that particular furnace.

A few additions and refinements made to the chart as described above enable it to record practically all the essential data involved. A grid is provided at the top of the chart for the scrap-loading cranes, in which a simple line records the actual period of operation of each crane. A number above each line indicates the scrap-handling road which it is serving, so that the operation of the cranes can at all times be referred to the actual bogies loaded.

The layout of the tracks on the furnace stage provides a running road with access by turn-outs at intervals on both sides to the charge-holding roads. The charge running road is intended to be kept clear of all standing traffic, but occasions may arise when, by leaving a train of bogies on such a track for a few minutes, whilst other bogies are moved out of an adjacent holding road, time can be saved. A grid is therefore provided for any running roads which may be used in this way.

Operation of the chargers is shown by thickening the line representing the overall charging period of each furnace during those periods when the chargers are actually unloading pans into the furnace. The addition of the hot metal is indicated by a hollow line, and this also indicates that the hot-metal cranes or the transfer car must have a clear path to and from that particular furnace at the beginning and end of the period. The chargers are generally intended to move the bogies into position for loading, and the locomotives will usually bring the trains as far as

the adjacent turn-out giving access to the furnace road, and take them from that point. Where the trains have to stand for a short period on the turn-out, this is shown by a thin double line along the furnace-road grid. Bogies in front of one furnace may sometimes be pushed along the furnace road by the charger to join others standing in front of other furnaces, and such movements are shown by inclined or (if the furnaces are adjacent) vertical thin double lines.

The combining or dividing of trains can be quite easily shown. All inclined full lines with arrow-heads indicate movements of trains of bogies by a locomotive, and the number at the commencement of the line is the total number of bogies moved. When the train is divided after the movement the number at the end of the inclined line shows the number of bogies detached at the first station, and the movement of the remainder can be followed by further inclined lines until all the bogies moved are accounted for. The joining up of trains is equally clear if the general principle is borne in mind that the figures at the commencement of every line give the number of bogies represented by the line.

When these charts had been fully developed it was found that, so far as the feed material or furnace stage system is concerned, they give all the information that can be obtained from the model, and at a much smaller expenditure of man-hours. They also have the advantage that every situation that arises is on permanent record, and the charts can consequently be used to extract all kinds of statistical information.

Results of the Study of the Stage Railway System at Abbey Works

The charts have since been successfully used to study the layout of other new melting shops, and have also been adapted for time studies of existing shops. To present the information obtained about the layout and operation of stage railway systems it will suffice to summarize the results of the study of the new melting shop at Abbey Works.

A plan of the stage railway system is shown in Fig. 12. The furnaces are of the fixed type, of 200 tons' capacity, and the charges will include 50% of hot metal. The composition of the charges was assumed to be precisely as set out in Fig. 6. Twelve-hour periods of operation were completely worked out for the following conditions on the plant :

(1) Twelve furnaces in operation, all taking 12 hr. from tap to tap.
(2) Eleven furnaces in operation, as in (1), No. 3 being under repair.
(3) Sunday, 2 P.M.–10 P.M., 12 furnaces in operation, all taking 12 hr. tap-to-tap. First three furnaces tap at 2.15 P.M., the next three at 4.15 P.M., three more at 6.15 P.M., and the last three at 8.15 P.M.
(4) Eleven furnaces in operation, taking from 10 to 14 hr. tap-to-tap, No. 7 under repair.
(5) As (4), with scrap packing density reduced from 1 ton per pan to 15 cwt. per pan.
(6) As (4), with the furnace line blocked opposite No. 7 furnace.

In addition, two 3-hr. periods were worked out to investigate the conditions arising (*a*) from the breakdown of a charger, and (*b*) from the blocking of the entrance to one scrap-handling station.

As a basis for all these studies the charging time (for the cold charge) was fixed at 3 hr., the charge to be put in, when possible, in three runs each of approximately ten bogies (full). As will be seen by comparison with Fig. 6, this time is considerably longer than the minimum of which the charger and supply system would be capable, because, as (it is maintained) is generally the case in well-designed shops, the furnace capacity to melt is the limiting factor. In none of the 12-hr. periods worked out were the charges so concentrated as in the limiting case considered in the preceding section, the charges being spread rather more evenly over the whole period. It may be noted that the proportions of charge-holding capacity differ slightly from those suggested. The details are :

	Bogies	Charges
Charge-holding roads	142	4·7
Scrap and materials-handling bays	89	3

The total capacity, approximately eight charges, is about equal to the suggested figure of six plus two charges for a 12-furnace shop. The number of magnet cranes (five) is one less than the suggested figure, and, of these, only four were generally assumed to be working. In planning the plant, the designers assumed a loading rate for bought scrap of 0·6 ton/min. for the magnet cranes, as against 0·43 ton/min. used in this report on the basis of actual time studies. This difference emphasizes the fact that the calculations of maximum capacity in the preceding section are conservative.

These investigations showed that for all the periods worked out it was possible to keep the bogies sufficiently quickly in circulation to maintain the supply of scrap and raw materials. The first four periods and the last one were actually worked out on the assumption that one locomotive only would be used on the stage railway. Some ingenuity in planning the movements of this locomotive was required, and it was found that the percentages of the total time during which the locomotive would have to be in continuous movement (inclusive of an allowance for coupling and uncoupling) was 68% for period (1), 78% for period (2), 73% for period (3), 85% for period (4), and 91% for period (6). Period (5) would have been impossible to work with one locomotive, and the chart showed that the two locomotives used would be in operation for 59% and 55%, respectively, of the period.

These percentages would certainly be appreciably higher in actual operation, as even with some form of centralized traffic control, conditions at the furnaces are not sufficiently stabilized in advance to enable the train movements to be so neatly dovetailed as was possible on these charts. This has been abundantly demonstrated in time studies at existing plants, as was also the unavoidability of extra movements occasioned by such contingencies as damaged couplings, etc. It was therefore concluded that two locomotives would certainly be required to operate the stage railway, and in order to minimize the idle time caused by mutual interference or by obstruction of their movements, they must be fairly sharply segregated into stage duties and supply duties, the

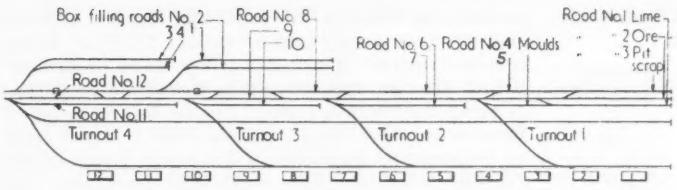


Fig. 12—Plan of stage railway for Abbey Works model

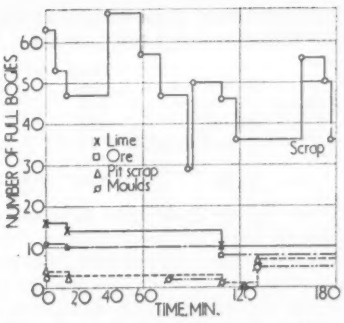


Fig. 13—Stock position on stage. Abbey Works model test

latter covering all movements between the scrap-handling and raw-materials bays and the charge running road. Period (1) was also worked out in this way with two locomotives.

It was arranged at the outset that a peak 3-hr. period should be selected from the charts as a test of the maximum capacity of the supply system, and the section of the chart for period (1), using two locomotives, which is reproduced in Fig. 15, was chosen. This period was worked out on the model, exactly as scheduled in the chart, by a combined team of operators from Messrs. Guest Keen Baldwins Iron and Steel Co., Ltd., the International Construction Co., Ltd., and the British Iron and Steel Research Association, on 8th May, 1947, at Port Talbot. The conditions do not quite tally with those chosen to represent the maximum demand for the purpose of calculation, where, by assuming absolutely simultaneous charging of half the furnaces, the problem is greatly simplified. Whilst free from any such suggestion of artificiality, the period chosen is representative of a fairly onerous duty which will regularly occur in practice. At the commencement of the period, three furnaces are in course of charging, two more have received their cold charges but still await their hot metal, two are fettling and due to commence charging during the period, and another two are tapped and fettled, and commence recharging during the period. Thus, nine of the twelve are at some stage of charging within the 3-hr. period, seven of them taking cold materials during this time. To make matters additionally difficult the three furnaces at the end of the shop most remote from the point at which materials enter, namely, Nos. 1, 2, and 3, have to be charged simultaneously about half-way through the period. The 3-hr. test period was actually worked through very smoothly on the model, and the situation at the close of the period tallied in every detail with the chart, showing that these charts can be used with confidence for studies of this kind.

It has been mentioned that the charge-holding capacity on the stage is less than that given by the suggested rule of a full charge for half the furnaces. The value of this rule is borne out by the fact that it was found necessary to have a train of twenty full bogies at the end of the hot-metal track opposite Nos. 11 and 12 furnaces in order to build up a sufficient stock on the stage to meet the impending demand, though this meant some interference with the delivery of hot metal to No. 11 furnace. The ladle crane would have to make a short travel of about 150 ft. after lifting the hot metal from the transfer car. Actually, there was still a large number of empty bogies in the charge-holding roads not yet cleared from the stage, and the scrap-stock position at the commencement was 63 full bogies. Figure 13 shows how this varied through the test period, falling to 36 bogies at the end. The full 12-hr. chart shows that the stock on the stage fell subsequently to 18–20 bogies, owing mainly to the time taken by the magnet cranes to overtake the peak demand rate. About $2\frac{1}{2}$ hr. after the end of the test period the stock of scrap on the stage is again over 60 bogie loads.

The chart shows quite clearly that the magnet cranes cannot be kept working at a uniform rate with a stage railway system, as there must be periods of waiting for empty bogies to be returned, and it is for this reason that as many magnet cranes are required with such a system as in the bench system. The percentage of time during which the magnet cranes were able to work during the peak 3-hr. period was 62, which just equals the overall percentage for the 12 hr. This means that the locomotives are not able to circulate bogies during the peak period at a speed sufficient to enable the magnet cranes to keep pace with the demand, even in a shop with the scrap bay situated as closely as possible to the stage.

During the peak 3-hr. period the stage locomotive was in movement for 77% of the time, and the supply locomotive for 50%. It was not possible to equalize the load between the locomotives without causing interference of movements on the stage. This is really the heart of the problem of stage railway systems, and somewhat detailed attention has been paid to this test because it shows more clearly than is possible from theoretical considerations that such a system is stretched to the limit in a shop of this magnitude. A percentage idle time of 23 would appear at first sight a sufficient margin, but, as has been mentioned, it pre-supposes that the locomotive makes at every point the optimum move in the light of future requirements for an hour or more, and it allows nothing for minor defects and incidents. Any attempt to relieve the situation by introducing another locomotive results in lost time due to mutual interference.

One possible way of relieving the situation, as in the case of bench systems, is to deliver the raw materials by conveyor or portable bunker, and the advantage to be gained is considerably greater in stage railway systems. The 3-hr. test period demonstrates very effectively the disproportionate amount of shunting caused by delivering the raw materials on bogies. The following figures are percentages of

the actual time of movement of the stage locomotive, and therefore total 100% or 2 hr. 19 min. :

Material	Time, min.	No. of Bogies per Charge	Percentage of Movement Time
Scrap	104	26	75
Lime and ore ...	24	3	17
Pit scrap and moulds	11	2	8
Total ...	139	31	100

These figures show that 17% of the actual working time of the stage locomotive is taken up in shunting raw materials. In practice, this proportion might be increased because the movements of individual bogies, unless carried out with considerable forethought, can easily entail a great deal of unnecessary movement of trains of bogies, as has been clearly shown in time studies in existing shops.

The disadvantage of handling the raw materials on bogies was also demonstrated in another way by the 3-hr. test. During the period, furnaces Nos. 1 and 3 receive their first charge at the same time that furnace No. 2 receives its final cold charge. This entails the division of the trains of bogies for each of the three furnaces. The whole of the first six bogies brought up to Nos. 1 and 3 furnaces contain scrap, the second part of the first charge comprising lime, ore, and pit scrap. The chart shows that to have worked in a proportion of lime and ore in the first rake would have been impossible without considerable delay in charging these furnaces, and probably in all subsequent events. This position therefore has to be accepted where adjacent furnaces are simultaneously charging, especially at the far end of the shop where there is no outlet from the furnace line.

The supply locomotive was in movement for 50% of the 3 hr., but its work was divided into fairly long periods of standing and periods of continuous activity. During the latter a disproportionate amount of time was occupied in assembling pairs of 10-bogie rakes from the separate scrap-loading roads into complete trains, and similarly in dividing empty trains. Moreover, each of these operations entails obstruction of the charge running road past the weighbridges. It was therefore agreed by all concerned in the test that it would be a great advantage to run the scrap-loading roads through as continuous tracks so that rakes could be assembled simply by pushing them up together, coupling, and pulling out. The result of this would be to give the supply locomotive a greater working margin during its periods of activity.

Conditions Arising from Breakdowns

A few remarks will be made, in concluding this section, on the conditions arising from some typical breakdowns. The breakdown of No. 2 charger in a position blocking No. 2 turn-out was examined. The defect was supposed to occur after 3 hr. of the 12-hr. operation period (4) (*see* page 204), and to last for 3 hr. before the defect was rectified. The main difficulty arises at Nos. 1 and 4 furnaces which at that point in the schedule are charging together. Only No. 1 charger is available for this duty. When No. 4 furnace is ready for its next run of scrap, hot metal is being poured at No. 8, and it is then impossible to get the bogies to the furnace. As a result, a 45-min. delay occurs in charging No. 4 furnace. Nos. 4 and 5 furnaces are taking a run of material together as No. 2 charger again comes into operation. Further delays of 8 min. each occur in charging Nos. 8 and 10 furnaces (which are then receiving their second and first runs of scrap respectively) owing to the fact that No. 7 furnace is under repair and the empty bogies have to be removed from No. 4 furnace. These delays are the minimum that could take place, and the organization to meet the situation would depend for its success on placing as large a number of bogies as possible in front of the furnaces being charged.

The case of a scrap-handling station being blocked for 3 hr. at the same point in period (4) was found not to incur delay, although the supply locomotive would have difficulty in maintaining stock on the stage. The position would be considerably easier as a result of the recommended alteration to the track layout in the scrap-handling bay.

Consideration was given to the situation arising if furnace repairs necessitate the blockage of the furnace line. The chief result would be that additional charges would have to be split in order not to overlap the furnace under repair, and this would still further intensify the duties of the stage locomotive.

Use of the Charts to Control Stage Railway Supply Systems

It will be fairly clear from the foregoing that in order to operate a stage railway system for melting shops of the magnitude of that at Abbey Works, close control of all traffic movements is necessary if delays are to be avoided. The charts used for these studies also offer a method of controlling the flow of materials through the open-hearth plant. What is envisaged is that the controller should sit at a desk in a central position on or above the furnace stage. He should be in telephonic communication with the melter in charge of each furnace and with the foreman in charge of the scrap-handling plant and the raw-materials yard, as well as with the melting-shop manager. In front of him on the desk he should have a pile of blank diagrams, similar to the charts, each sheet corresponding, say, to 6 hr. He will plot the operation of each furnace and all traffic movements as far in advance as the available information will allow. He will communicate each movement to the locomotive, charger, and crane drivers, as well as to others concerned, by a public-address system, such as is used in railway stations, giving each instruction only through those loudspeakers in the part of the plant affected. This would ensure that all concerned knew exactly what was required. The operation of the track points could then be left to the shunter.

Without some such centralized control occasional confusion and delay, and a multiplicity of avoidable movements, perhaps entailing additional and unnecessary locomotive power, would seem inevitable. The diagrams would also provide the management with an invaluable record of the operation of the plant, which should enable causes of delay to be readily ascertained and steps to be taken to prevent their recurrence.

TIME STUDIES AT EXISTING WORKS

It has been explained that the basic data used for computing the performance limits of chargers and

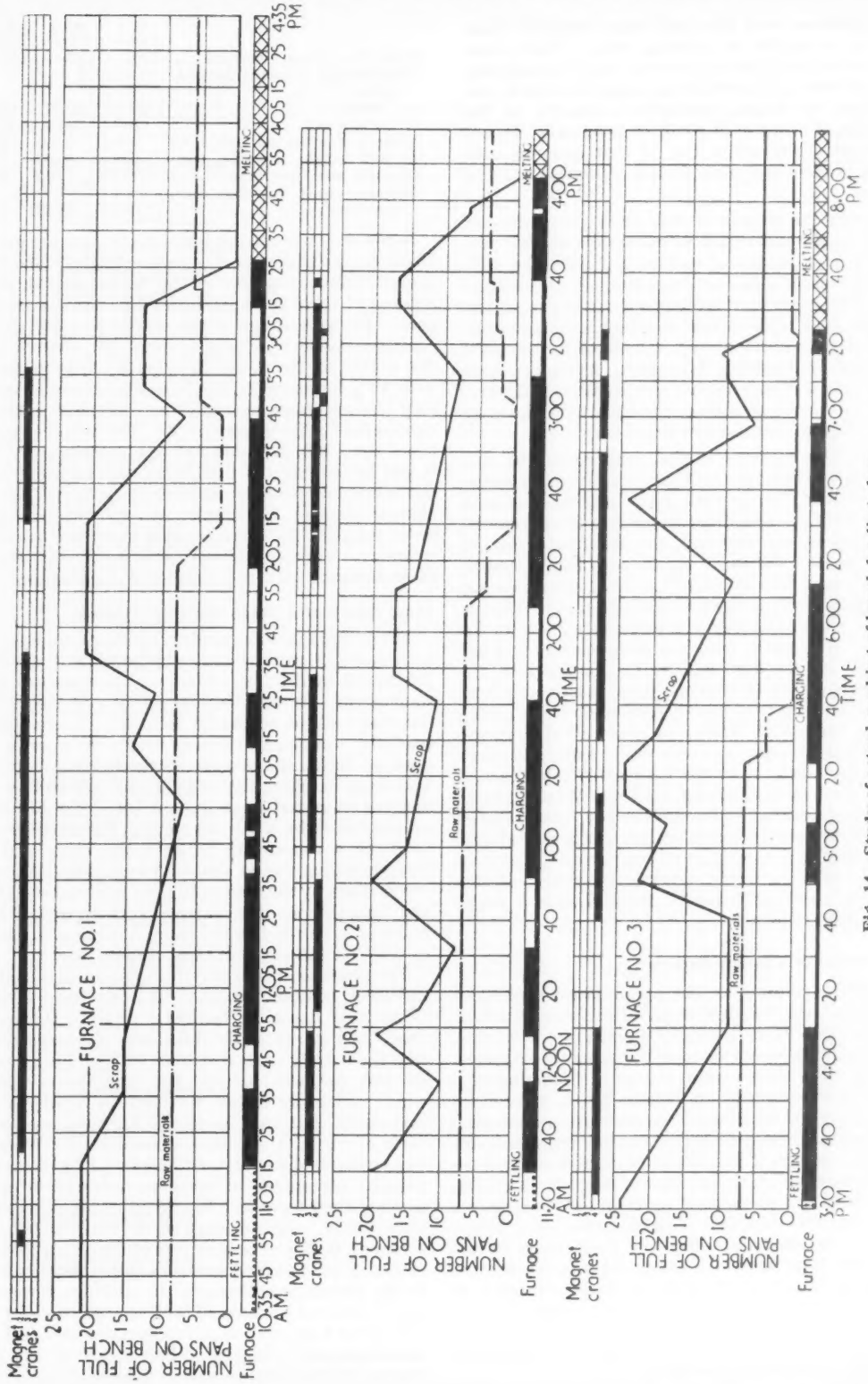


Fig. 14—Study of actual working of bench loading shop

supply systems were obtained from extensive time studies at a number of existing works. These time studies were also of value in several cases in analysing causes of delay and ascertaining means by which, and the extent to which, productive capacity or the proportion of scrap used could be increased. Charts of the type illustrated in Fig. 15 were used for most of these studies and proved their value for work of this type.

Although the details of this work are mainly of interest to the individual firms involved, they are of value as a means of acquiring familiarity with practical aspects of the problems studied. One feature of the studies, however, is of importance to the general problem ; that is the extent to which in practice the performance conforms to that calculated for the plant on the lines indicated in this report. As may perhaps be anticipated from what has already been said, there is in this respect a marked contrast between the stage railway system and the bench system.

Some of the systems studied could hardly be considered to represent the best features of either system. Data obtained, for instance, for a melting shop with a stage railway consisting of a single track running down the back of the stage, can be of little general interest today ; the same applies to a bench loading shop in which the layout of the track on which the bulk supplies are brought in is so severe a bottleneck that the magnet cranes are frequently held up for supplies. The latter fault is a common one and has no doubt largely been responsible for much of the discredit which bench systems appear to have acquired. A moment's reflection, however, will show that nothing like the amount of track and space allotted to the newest stage railway systems would suffice to eliminate such defects, since the material is being carried in a so much more concentrated form. Where the two systems are reasonably well laid out, the essential difference is that the bench system works very closely to schedule, but the stage railway system is subject to a complex of traffic movements which entail a practical limit to its capacity, short of what it might be expected to attain.

Time Study of a Bench System

Figure 14 illustrates the performance of a shop working on the bench system. The furnaces are of 90 tons' capacity and take 100% cold-metal charges. The time studies were made on two separate occasions, but three furnaces were charging simultaneously during the time study on furnace No. 1, when three chargers and three magnet cranes were in operation. The performance at each furnace was representative of the conditions if half the total number of furnaces had been charging, the number of magnet cranes and chargers in this shop being equal to half the number of the furnaces installed. Two of the furnaces (Nos. 1 and 3 in the diagram) completed their charge in just over 4 hr. ; the third took longer (4½ hr.), not because of any limitation in charging or supply capacity, as is clearly shown in the diagram, but simply because the furnace was of an older type and unable to melt the charge so quickly. Particulars of the charges of the three furnaces are as follows :

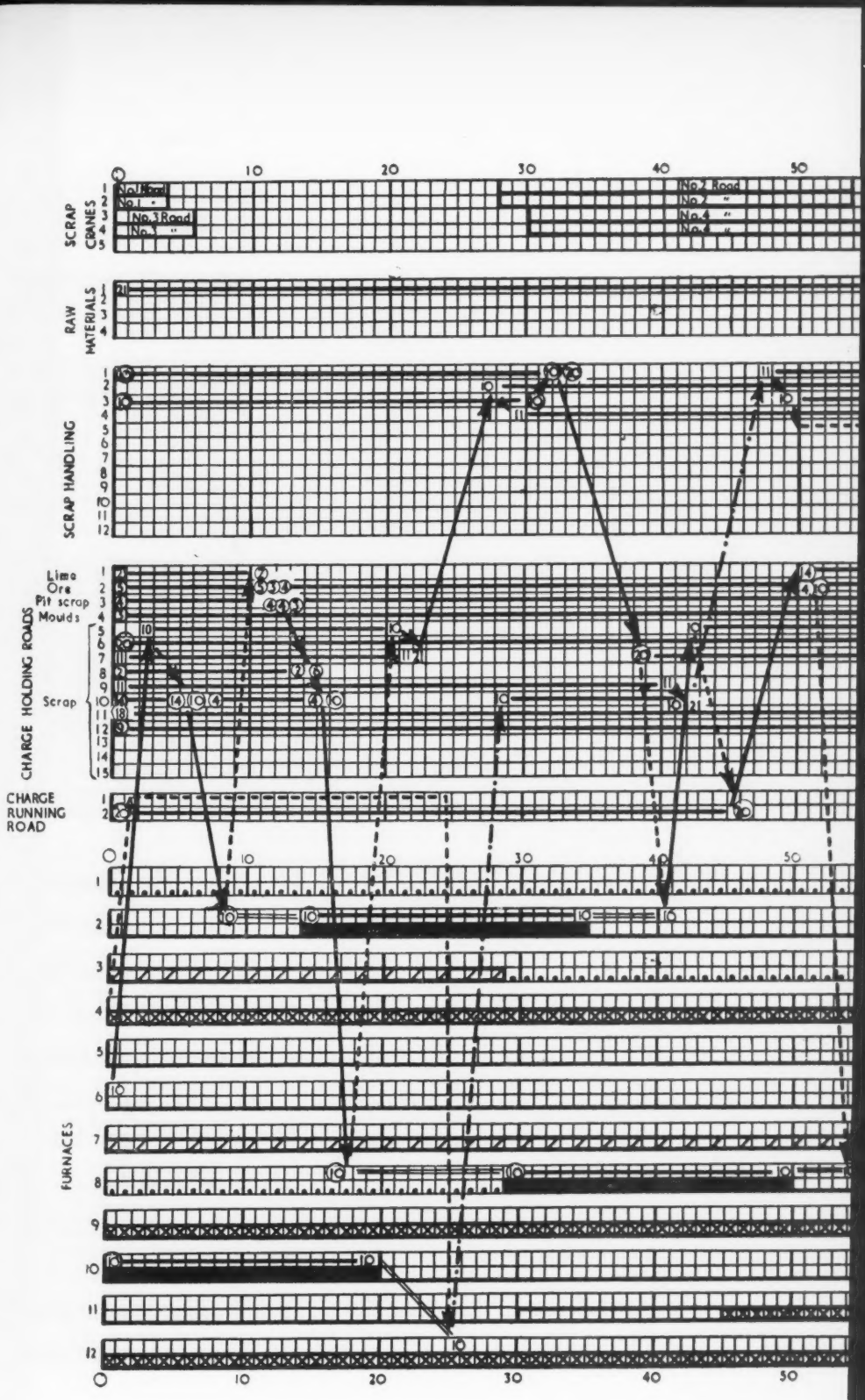
	No. 1 Furnace	No. 2 Furnace	No. 3 Furnace
Total No. of pans charged ...	129	149	150
Total weight of metal charged, tons :			
Scrap	69·5	63·2	67·7
Pig iron	26·7	30·4	29·5
Weight of scrap per pan, tons	0·64	0·50	0·52
Overall weight per pan, tons	0·8	0·66	0·67
Charger rate, min./pan ...	1·17	1·25	0·97
Magnet crane loading rate, tons/min.	0·51	0·43	0·48

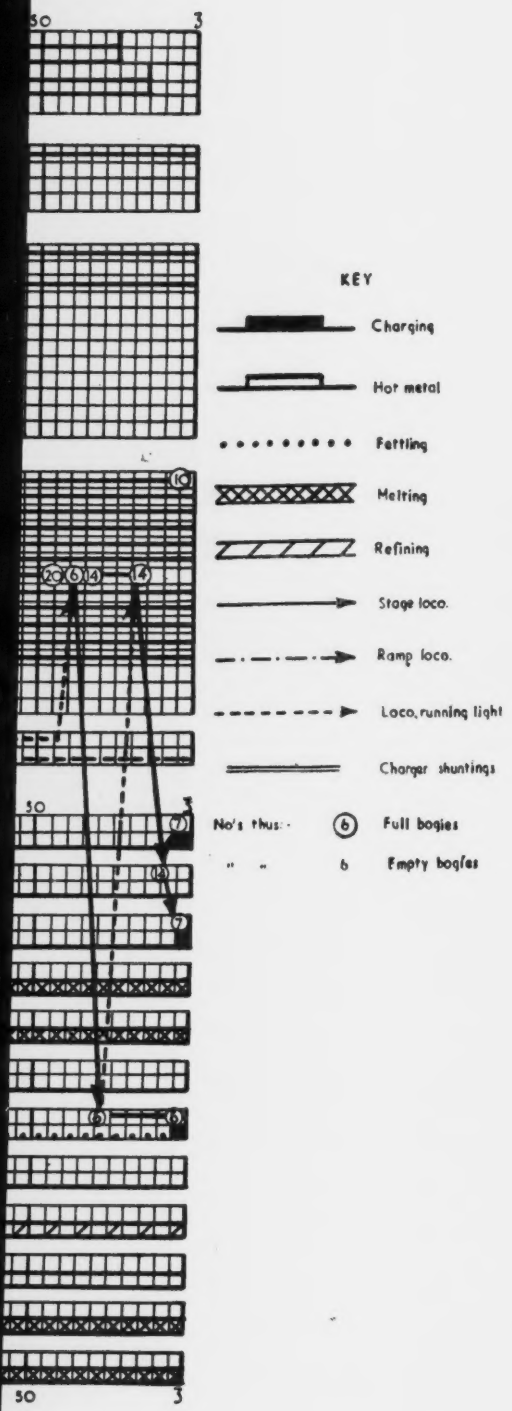
In the shop under consideration the pans are loaded direct on the stage, so eliminating lifting. The only charge-holding capacity is the bench on the stage holding 21 to 25 scrap pans and 6 to 8 raw-materials pans. The percentage of the charge prepared at the commencement of charging was 23% for furnace No. 1, 18% for No. 2, and 22% for No. 3, as compared with 19% indicated in Fig. 9 as the minimum necessary (for minimum charging time) when no lifting is carried out by the magnet crane. The actual charging times were 242, 276, and 241 min., respectively, but it will be seen that if the charge had been put in in the minimum possible charging time, as set by the charger (namely, 170 min.), the supply system could have supplied the charger with the same prepared quantity. Thus the actual performance was closely in accordance with the calculated performance.

Time Study of a Stage Railway System

The performance of a modern melting shop equipped with a stage railway and charge-holding roads is illustrated in Fig. 16. Rotating chargers are used, so that the ' furnace line ' is actually at the rear of the stage and is separated from the charge-holding roads by the charge running road, and may in this case be reckoned also as charge-holding capacity. The scrap-handling bay is at some distance from the melting shop and is at ground level, the lift being accomplished by a 1-in-30 ramp. The average time to make a round trip between the stage and the scrap-handling bay is about 25 min. Raw materials are handled by the crane and portable bunkers. They are brought up the ramp in bulk to the large bunkers at the end of the shop, but are not handled in pans on the stage railway proper.

The plant comprises five tilting furnaces of 200 and 250 tons' nominal capacity, and two fixed furnaces of 80 tons' capacity, besides a mixer. During the time study one of the fixed furnaces was under repair. The time study extended over 12 hr., during which all the furnaces, except for the 80-ton furnace which was under repair, received the whole of their cold-metal charges. As the tilting furnaces have a cycle of 18 to 20 hr. this represented conditions of concentrated demand, and furnace *F* was given a reduced percentage of scrap in order to bring the tapping time forward. Figure 16 shows 4 hr. of the time study, commencing at 8 P.M., when three furnaces, *B*, *E*, and *G*, were just commencing to charge (*E* and *G* had received small charges of limestone only in the preceding half-hour). In addition, furnaces *A* and *C* received portions of their charges, and for 2 hr. out of the 4 hr., four of seven furnaces installed were simultaneously charging. Particulars of the scrap charges to the furnaces are as follows :


SCRAP CRANES
No.1 Road
No.1 "
No.3 Road
No.3 "
No.2 Road
No.2 "
No.4 "
No.4 "
RAW MATERIALS
SCRAP HANDLING
CHARGE HOLDING ROADS
Lime
Ore
Pit scrap
Moulds
Scrap
CHARGE RUNNING ROAD
FURNACES
10
20
30
40
50



period of operation of Abbey Works model

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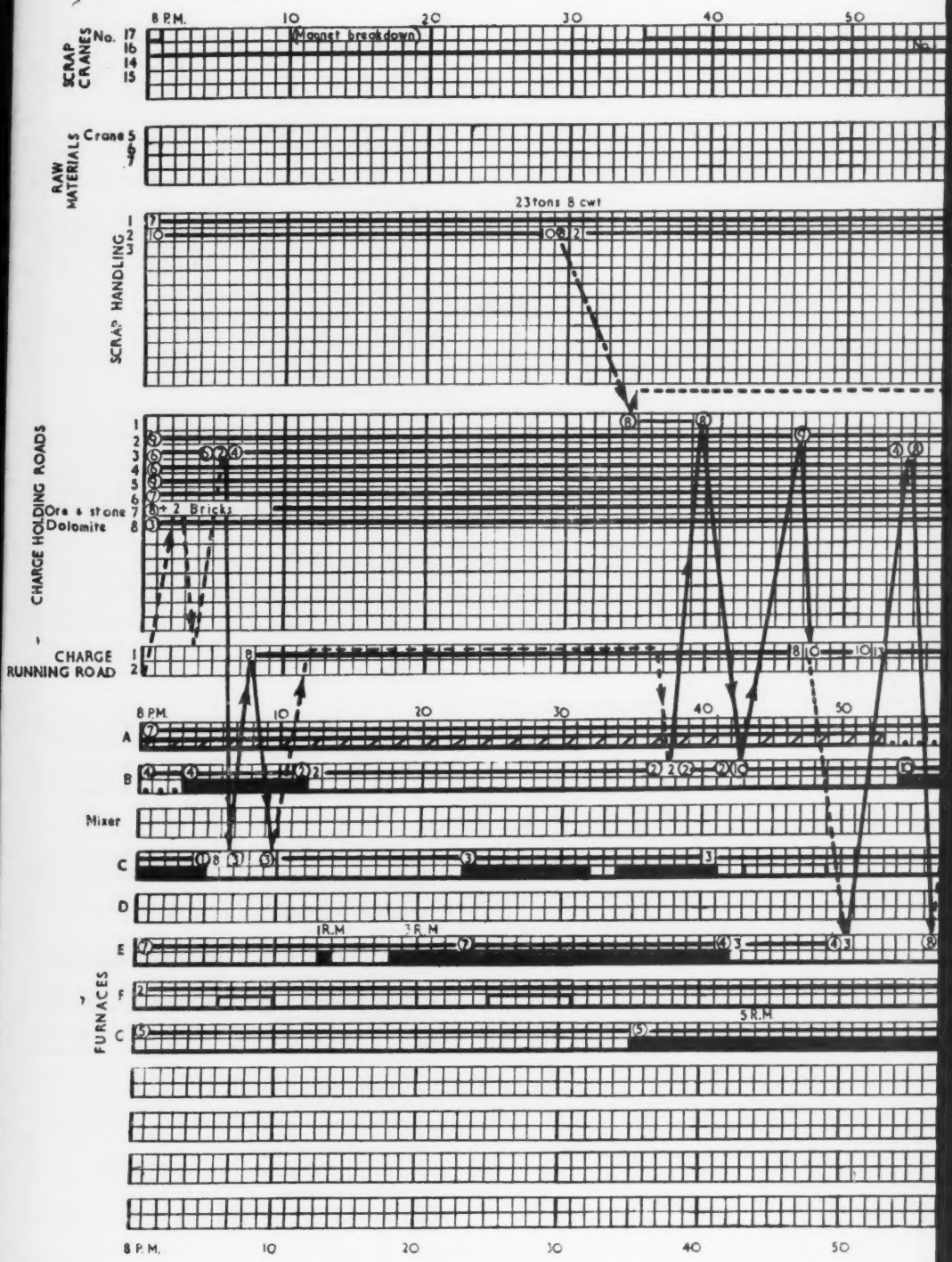
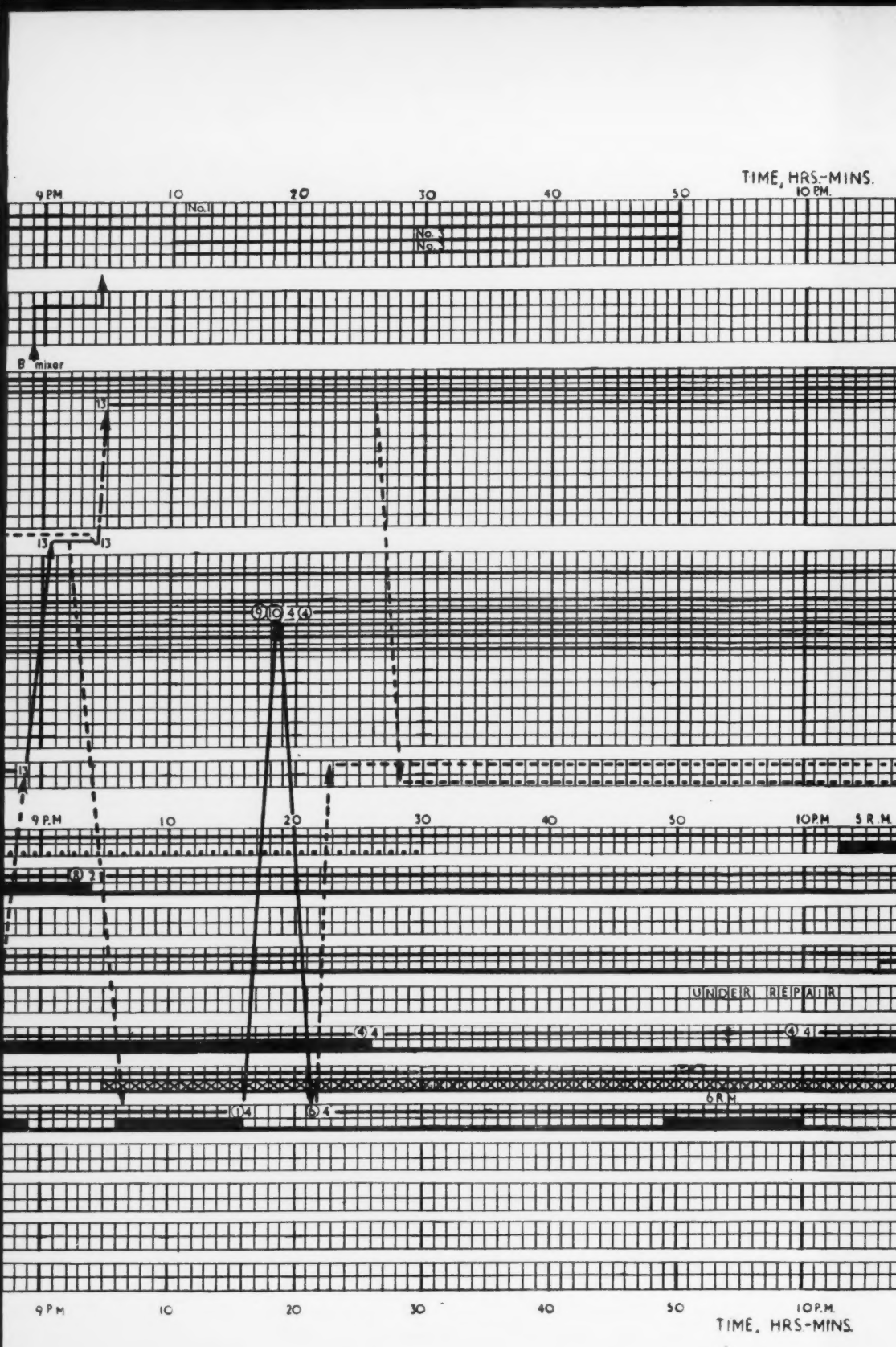
CHARGE HOLDING ROADS

RUNN


8 P.M.
10
20
30
40
50
SCRAP CRANES
No. 17
16
14
15
(Magnet breakdown)
RAW MATERIALS
Crane 5
6
7
23tons 8 cwt
SCRAP HANDLING
1
2
3
CHARGE HOLDING ROADS
Ore & stone
Dolomite
+ 2 Bricks
CHARGE RUNNING ROAD
A
B
Mixer
C
D
E
F
G
1R.M
3R.M
5R.M
FURNACES


TIME, HRS.-MINS.
9 PM
10
20
30
40
50
10 PM.
No. 1
No. 2
No. 3
B mixer
13
13
13
9 10 4 6
9 P.M
10
20
30
40
50
10 P.M
5 R.M.
8 2
UNDER REPAIR
4 4
4 4
10 4
6 4
6 R.M.
9 P.M
10
20
30
40
50
10 P.M.
TIME, HRS-MINS.

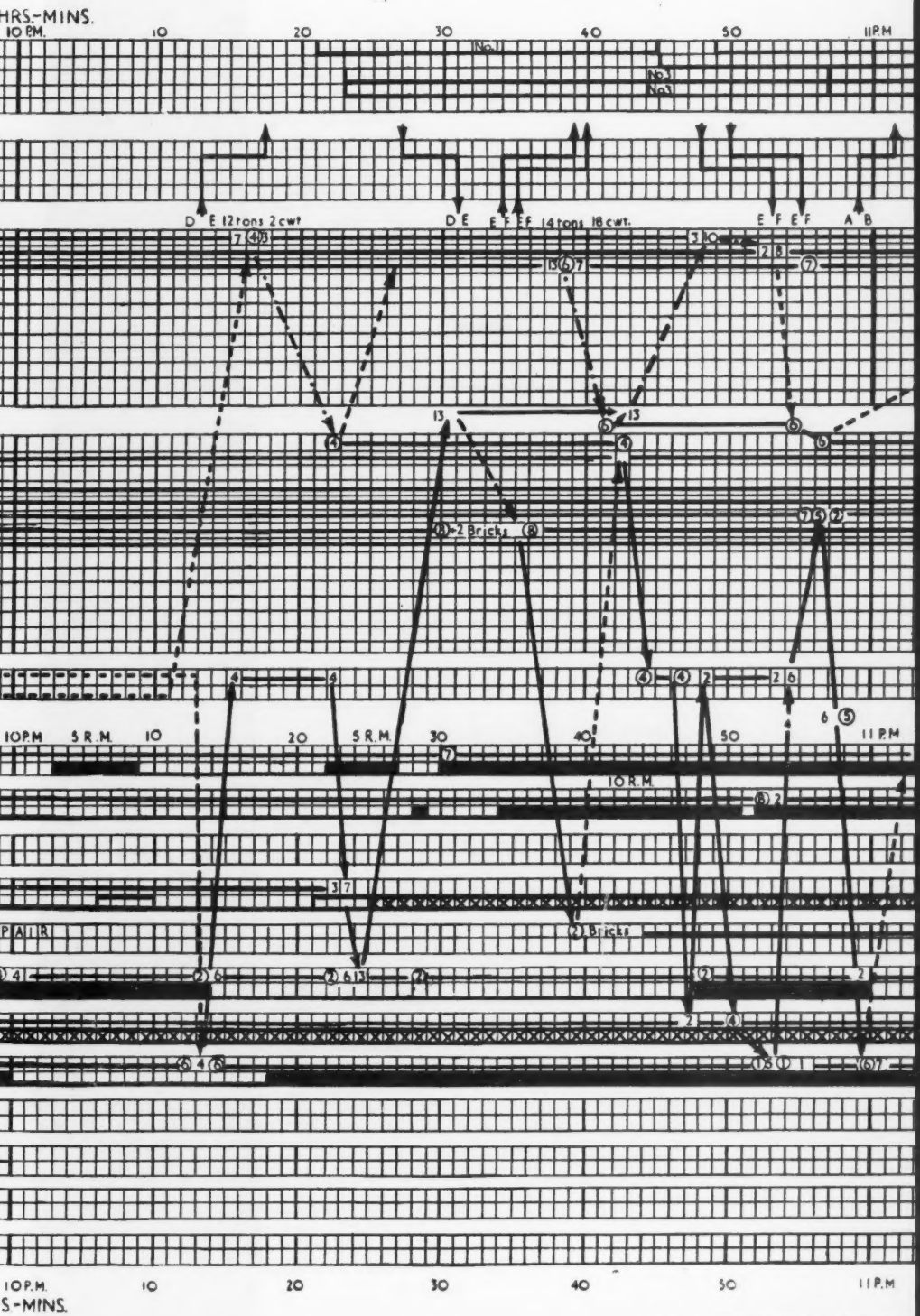
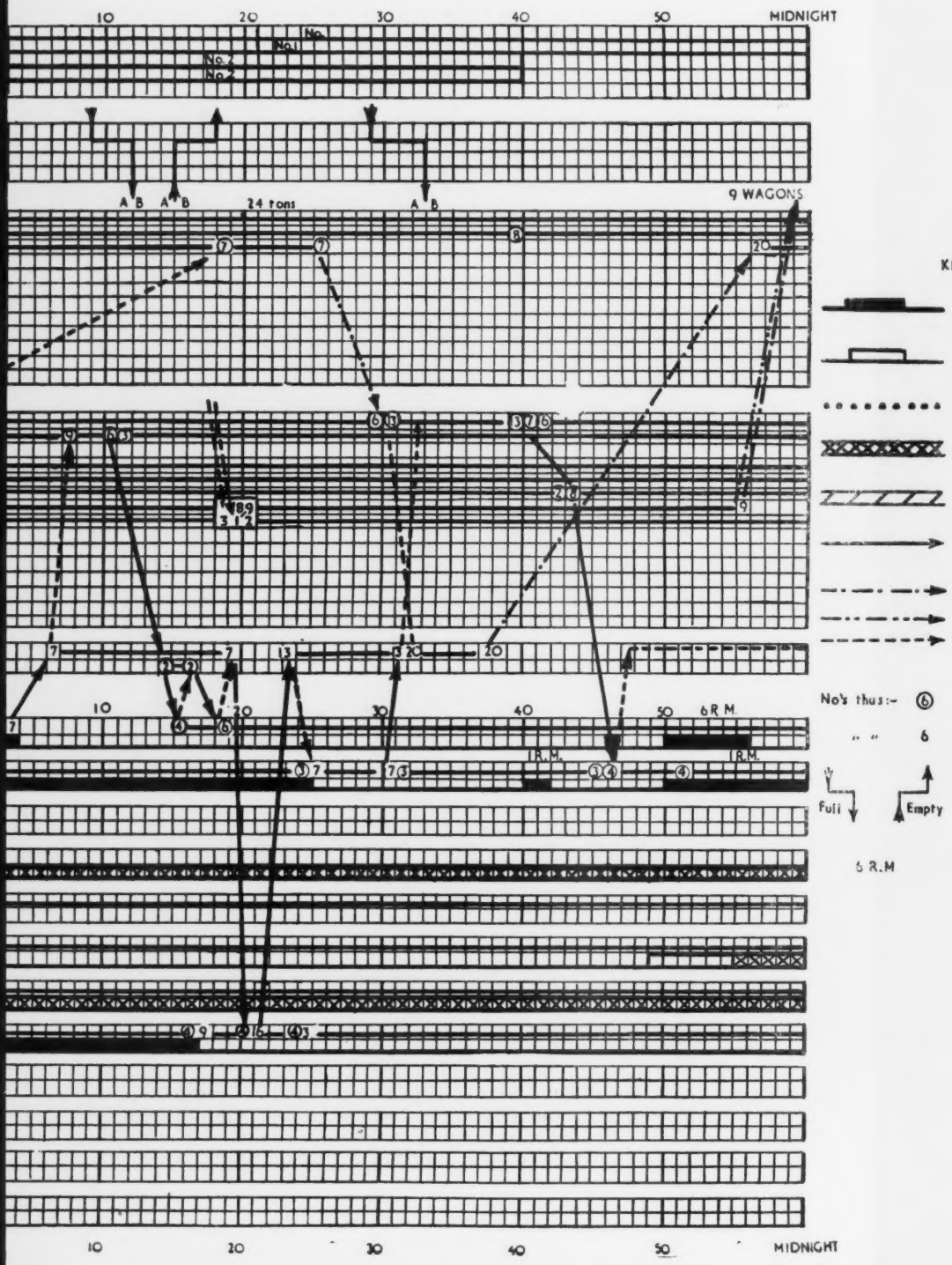


Fig. 16—Time study of actual w



orking of stage railway shop

[Diamond
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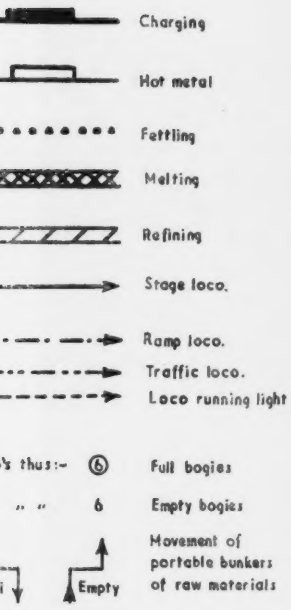


[*Diamond and Frankau*
[*between pp.* 208–209

Furnaces	A	B	C	E	F	G
No. of pans of scrap charged	92	58	80	55	40	115
Total weight of scrap charged, tons ...	86	42	84	61	47	80
Weight of scrap per pan, tons	0·94	0·72	1·05	1·1	1·17	0·70
Hot metal, tons	187	153	169	52	143	153
Percentage of scrap	31·4	27·2	33·3	54·3	24·6	34·3
Duration of charge (cold material), hr.	4·7	5·8	3·75	3·17	3·0	6·7
Charger working rate, min./pan ...	1·11	1·32	1·25	1·42	2·08	1·38

Note—Lime and ore are handled by a separate portable bunker system

The number of (five-pan) bogies in circulation was 88. At 8 P.M. there were 61 full bogies and 10 empty bogies on the stage, and in the scrap-handling yard there were 17 empty bogies. On the basis of the actual tonnages charged to the furnaces, 58 full bogies would represent complete scrap charges for half the furnaces, and according to the suggested rule for stage railway systems, there should be this number on the stage plus 19 (one-third of the charge for half the furnaces) in the scrap-handling yard. (This, of course, is for the scrap percentage prevailing at the time, namely, 30% in the tilting furnaces and 55% in the fixed furnaces.) The actual position at 8 P.M. therefore agreed closely with the hypothetical starting conditions for periods of maximum charging, so far as the stage is concerned, but the quota of bogies in the scrap-handling yard were empty ; there were also ten additional empty bogies on the stage. Figure 17 shows the fluctuation in the stock position on the stage over the 4 hr. from 8 P.M. to midnight, represented by the chart in Fig. 16. It will be seen that the stock fell by less than one-half during this period. Charging was at a slower rate than the maximum of which the chargers were capable, for reasons connected solely with the furnaces or the general operation of the plant. There was at no time any shortage of scrap or lack of chargers, as can be seen from the chart. The 10 P.M. change of shift fell within the period, and the effect of this is very noticeable ; both locomotives, for instance, stand a considerable time for oiling, etc. The chart also shows that the number of locomotive movements was greater than would have been shown in a planned schedule, such as that drawn up for the Abbey Works melting shop (Fig. 15). The percentage of movement time for the stage and supply locomotives during the 4 hr. was 58% and 24% respectively or 79% and 41% if the shift-change interval be omitted.

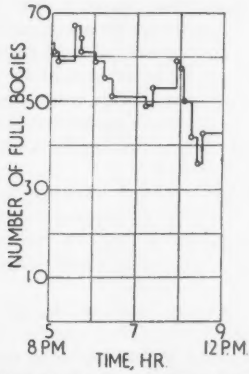


Fig. 17—Variation of stock on stage during peak period of time study. Stage railway shop

The overall percentages for the 12-hr. time study were, however, 57% and 56% respectively, the supply locomotive being relatively idle between 8 P.M. and 10 P.M., as all available loaded bogies had already been taken to the stage. These figures show that the supply system had not reached its maximum capacity during the time study.

Maximum Capacity of the Stage Railway System Studied

The maximum capacity of the system was investigated on the basis of the data obtained, by means of hypothetical charts, keeping within the known performance of each item of the plant, as shown by the time study. The method was to ascertain to what extent the scrap percentage to the tilting furnaces could have been increased without causing delay, for the same charging sequence as in the time study, and assuming the same overall charging times. From preliminary studies it was estimated that the limit of the supply system would be reached, owing to traffic congestion on the stage, when the amount of scrap to the tilting furnaces exceeded 40% (the percentage to the fixed furnaces remaining at 55). A hypothetical chart was therefore worked out in detail for this condition. The average pan weight was assumed to be 0·7 ton per pan.

With 40% of scrap to the tilting furnaces, the charge-holding capacity, according to the requirements laid down in the theoretical study, should be 76 bogies on the stage and 25 bogies in the scrap yard. In the hypothetical study, therefore, it was assumed that the number of bogies in circulation was increased from 88 to 101. As there were 77 loaded bogies on, or at the entrance to, the stage at the commencement

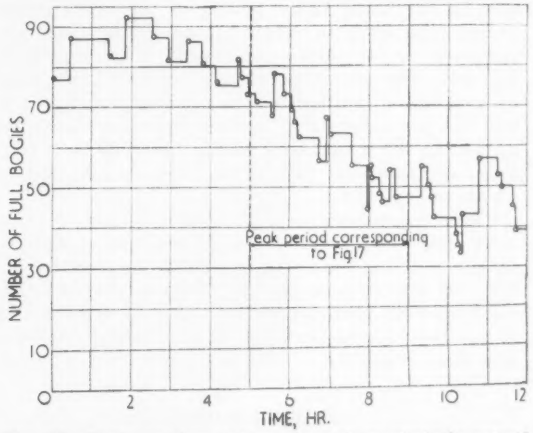


Fig. 18—Estimated variation of stock on stage in actual stage railway shop, with maximum scrap charge and optimum number of bogies

of the actual time study, the only modification necessary to the starting position was to suppose the balance of 24 bogies to be all in the scrap yard in course of loading. This would easily have been possible as no charging had taken place for some hours previously.

The stock position on the stage would in these circumstances decline as shown in Fig. 18, and the percentage movement times for stage and supply locomotives during the second 6 hr. of the period (when the amount of stock would depend entirely on the rate of circulation of the bogies) would be 72½% and 65% respectively, supposing none but essential movements to be made. These percentages do not include time for the locomotives to refuel, for which allowance was made in the diagram. It is interesting to note that the relative movement times of stage and supply locomotive are broadly similar to those worked out for the new plant at Abbey Works, and, as in that case, it would not be possible to equalize them, because interference would then occur between the two locomotives on the stage.

Figure 18 shows that the stock position would remain at all times above the permissible minimum, though probably only sufficiently so to offset the extent to which the maximum demand of the actual charging sequence followed falls below that of the simultaneous charging periods assumed in the theoretical case. Bearing in mind that the locomotives can never spread their work evenly over a period of hours, since they must follow the fluctuating demands of the chargers, it will be understood that the percentages given above for six hours' continuous working are about the practicable limit.

In the hypothetical case, as in the actual time study, the average charging time of the tilting furnaces was 5 hr., as compared with a minimum charging time of 2·8 hr. (Fig. 6) possible for the chargers, and over 3 hr. for the fixed furnace, as compared with a minimum of about 2 hr. set by the charger. It will be seen, therefore, that the supply system is at or near the limit of its capacity at a point far short of the limit of the chargers.

The four magnet cranes worked for an average of 56% of the total 12-hr. period of the actual time study, with 30% of scrap to the tilting furnaces, increased to 61% during the peak 4 hr. shown in Fig. 16. The overall percentage with 40% of scrap worked out at 74·1% from the hypothetical diagram, but the average rate of loading, taken to be equal to that in the actual time study, was only 0·28 ton/min., as compared with 0·43 ton/min. assumed in all the calculations.

These conclusions were subsequently put to practical test. The overall average percentage of scrap to the melting shop was gradually increased from 35% to a maximum of 42% (with some variation week by week) during the following four months, and it has been found that the limit of the system has now been reached.

CONCLUSIONS

(1) For quickest melting time the open-hearth furnace should be charged at an even rate continuously maintained over the charging period, and not intermittently at a higher rate.

(2) The fastest rate of operation required of charging machines, therefore, is the uniform rate at which the maximum weight of cold materials required will be put into the furnace in the shortest time in which the furnace can accept the charge, with the minimum average pan weight to be expected, and with an allowance for observation, control, and contingencies.

(3) Existing types of charging machines are able to charge at a faster rate than can be accepted by furnaces of present design, without becoming choked, and in practice charging is always carried out intermittently.

(4) The fixed charger, taking pans from bogies immediately in front of the furnaces, can charge at the rate of two pans per minute, whereas the rotating charger operates at an overall rate of rather less than one pan per minute. Empty pans can, however, be replaced without interrupting the rotating charger, whereas the fixed charger must, when the maximum number of furnaces is charging, wait whilst rakes of empty bogies are replaced by rakes of loaded bogies. The net result is that the minimum charging time for the fixed charger is only about 20% shorter than for the rotating charger.

(5) The number of chargers in a melting shop should be equal to the maximum number of furnaces required to be charged simultaneously at the maximum rate of charging, otherwise intermittent working is unavoidable, and delay may arise in dovetailing the charging ' runs ' of two furnaces.

(6) The maximum number of furnaces to be charged simultaneously at the maximum rate, may be taken as half the total number of furnaces installed. The theoretical loss of output due to not being able to charge a greater number together is generally less than 5%, and this is discounted by the necessity to spread tapping times and to minimize irregular working in the mills.

(7) The supply system from the scrap and raw-materials loading bays to the stage should have a sufficient capacity to replace—in readiness for charging other furnaces—at least one-third of the total charge for the maximum number of furnaces to be charged simultaneously during the minimum charging period.

(8) To ensure that the requirement in (7) can be met, the charge-holding capacity on or behind the stage should be sufficient to accommodate one complete charge for half the number of furnaces installed, and stage railway systems should in addition have capacity for one-third of this quantity in the scrap-handling bay, as there is insufficient time to circulate and reload empty bogies during the minimum charging period in such a system.

(9) On the basis of an average loading rate of 0·43 ton/min., which is representative of existing practice, the number of magnet cranes should equal the number of chargers in both stage railway and bench systems.

(10) So long as the rotating charger can charge a furnace at a rate quicker than the furnace can assimilate the charge (which appears to be the case even for the most modern furnaces), the limit of the capacity of a bench system is the ability of the magnet cranes to

load and lift scrap to the stage. The limit is reached for furnaces of over 100 tons' capacity taking 100% cold charge. For a 50% cold charge the limit is a furnace capacity exceeding 200 tons, but if 20% of the cold charge is mill scrap loaded at source, and if the raw materials are delivered by conveyor direct to stage level, the limit has not been reached by fixed furnaces of the greatest capacity so far contemplated. The limit is also not reached in the case of tilting furnaces of the largest capacity taking 40% of cold material.

(11) Stage railway systems are not limited by the capacity of the magnet cranes, since, contrary to bench systems, these can be increased in number without causing mutual interference, provided that a proportionate increase in the holding capacity of the tracks in the scrap-handling bay is made. A more serious factor is congestion and mutual interference of train movements. This limits the stage railway system to about the same capacity as the bench system, and some form of centralized traffic control would be essential to attain the maximum capacity of such a system in the case of very large melting shops.

(12) The alleviation of congestion to be attained by delivering raw materials separately by conveyor to the stage is even greater in stage railway systems, as a disproportionate amount of shunting is involved in placing bogies of lime and ore in correct charging sequence. In fact, in certain circumstances, it is not possible to do this without delay in a stage railway system working at maximum capacity, and the charging sequence may have to be modified accordingly. It is therefore considered that in all modern melting shops raw materials should be delivered by separate conveyor systems, and any difficulties in metallurgical control of the charge should be tackled by automatic weighing and recording machines at the bunker chutes.

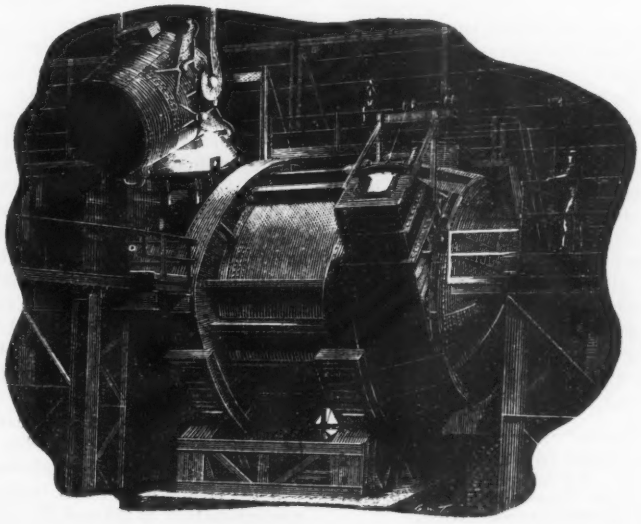
(13) A considerable increase in the maximum capacity of bench systems could be effected if the duty of replacing empty pans by loaded pans could be carried out by some means other than the magnet cranes. Such a system is suggested. It is considered that a bench loading system arranged in this way would have ample capacity for any melting shop at present contemplated.

(14) Apart from the question of capacity, every advantage in capital cost, cost of maintenance, and cost of power, also freedom from incidental delays, lies with the bench system, which eliminates the daily movement of hundreds of tons of dead weight in the form of pans and bogies over an aggregate distance that may amount to several miles.

(15) Both systems have nearly reached their limits in the most modern plants. It is proposed that the first line of attack for the future should be the development of the bench system, on the lines suggested, with a longer-term study of the possibilities of preparing and handling scrap in bulk by some form of conveyor system and perhaps new types of charging mechanism.

Acknowledgments

Acknowledgment is due to several firms who afforded facilities for the study of the practical operation of open-hearth furnace charging systems, and especially to Messrs. Guest Keen Baldwins Iron and Steel Co., Ltd., the Steel Company of Wales, Ltd., and Messrs. Colvilles, Ltd. Mr. W. F. Cartwright, M.I.Mech.E., was largely responsible for initiating the work on the layout of stage railway systems, and to him the authors' thanks are due for the opportunity to make use of the Abbey Works model. The authors also would like to acknowledge the extensive work carried out, especially in compiling the time-study records, by Mr. A. G. H. Coombes, B.Sc., while he was a member of the staff of the Plant Engineering Division of the British Iron and Steel Research Association.



The Influence of Heat Transfer on Open-Hearth Furnace Charging Rate

By M. W. Thring, M.A., F.Inst.P.

SYNOPSIS

Model experiments and calculations were used to decide whether increase in the rate at which the charge can be inserted into an open-hearth furnace will give an improvement in the total melting time. The model consisted of paraffin wax melted by a constant radiation from above and showed that assessment of the time to melt the charge below the liquid surface is not a fair way of assessing the merits of different charging schedules; only the time for complete melting can be used. A theoretical analysis then showed that for a given gross downward radiation the shortest possible melting time is obtained when the heat never has to pass through a thermal resistance before being absorbed as temperature rise. This means that it is of no advantage to put in the charge faster than the heat-transfer rate will permit, and in fact in some cases putting it in too fast can cool the furnace excessively and so reduce the gross downward radiation. If the charging must be stopped at any point before all the charge is inserted, because the furnace is becoming too full, or too cold, then the heat-transfer rate is the bottleneck. If, on the other hand, it is necessary to reduce the fuel-input rate from the maximum during the charging period then the charging is too slow. The latter usually occurs only when there is a delay in the arrival of materials, but if new furnaces are designed with a larger bath area per unit weight or with more rapid combustion rates, this state may be reached more frequently. The ideal charging process is uniform insertion at a rate such that the roof is kept always just below the maximum safe value while the fuel is being burnt at the maximum rate.

STATEMENT OF THE PROBLEM

It is often suggested that the melting period in the open-hearth-furnace cycle could be considerably shortened if the charge could be passed into the furnace more rapidly. Recent American publications indicate that plans are being worked out for removing the whole side of the furnace in order to insert the charge in a negligible time. It is, of course, obvious that the longer the doors are open for inserting the charge, the greater will be the cooling of the furnace due to the excess air drawn in through the open door. This effect is likely to be just as bad with apparatus in which the side of the furnace is removed as with the present arrangement. In order to decide future policy in regard to charging, it is necessary to determine the mechanism by which the charging procedure affects the melting time—is the melting time primarily affected by the length of time the steel is in the furnace, or is it primarily governed by other factors ? Evidence is brought forward in the present paper to show that the melting time is usually fixed by the heat-transfer conditions and not at all by the length of time the charge is in the furnace. It appears, in fact, that in such cases for a given flame radiation the melting time can be reduced only by reduction of the time average of the reradiation from the surface of the charge. Since the charge as a whole must increase in temperature during melting, this time average cannot be reduced below a certain minimum value. This minimum value is shown to occur in the case where the temperature of the top surface of the material in the furnace is below or equal to that of the material lower down, all the time until melting is complete. Too rapid charging can in fact be one of the causes of the actual melting time lying above this minimum.

A further question which arises is the effect of the bulk density of the charge material. Is a very light scrap a serious burden on the process only because it occupies a greater volume in the furnace and requires to be charged in more pans, or does its very low thermal diffusivity mean that it absorbs heat in the furnace less rapidly ?

Three possible methods of answering these questions about charging can be considered :

(1) *The use of the open-hearth furnace itself.* This method is subject to the inherent difficulty that it is necessary to operate a very considerable number of charges with each alternative arrangement owing to the inherent variability, before any conclusions can be reached, and that, even then, unavoidable systematic variations in furnace conditions and other factors during these charges make it almost impossible to draw any definite conclusions.

(2) The second method is *pure calculation* of the process of melting the steel. This method is subject to the difficulty that the complicated geometrical shape of the material and the effects of the presence of slag cannot readily be represented mathematically.

(3) The third method is to *build a model* in which, as compared with the furnace itself, conditions can be controlled fairly accurately and a number of experiments can be carried out with each arrangement, with everything else controlled. As compared with pure calculation, it is possible to obtain with a model, a fair representation of the essential geometrical factors in spite of their complexity. On the other hand a model can be expected to give only qualitative results, *i.e.*, a possibility of seeing what happens, and qualitative comparison between alternatives.

The method which was, in fact, adopted is therefore a combination of (2) and (3). First, qualitative model

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experiments gave a much better insight into what goes on inside the furnace ; then, order-of-magnitude calculations based on this insight show that the general picture of the process is correct ; and finally, quantitative model results are used to give a statistical evaluation of the results of the various differences posed above.

QUALITATIVE MODEL RESULTS

Laboratory methods of melting almost always involve heating the material from the bottom so that natural convection carries the material to the surface and the coldest material is always nearest to the supply of heat. The open-hearth furnace, on the other hand, is a melting process upside down, in which the heat is provided from the top while the liquid floats on top of the unmelted material. A qualitative model of the same process can therefore be provided by melting any material with a relatively sharp melting point which sinks in its own liquid in a dish, by means of radiation from a source situated above the surface. Paraffin wax has been used in the present experiments.

In order to obtain crudely approximate geometrical similarity, elliptical piedishes have been used and a longitudinal electric heater provided a source of radiation, as shown in Fig. 1. Details of the experiments are given in Appendix I. If the power input to the electric element is maintained constant its temperature will be practically unaffected by the surface temperature of the paraffin wax, and hence the *gross* radiation falling on the surface of the wax will remain constant. This corresponds to an open-hearth furnace with an opaque flame, in which the rate of heat supplied can be made very great so that the roof can be brought up to the safe limiting temperature very quickly after charging and then be maintained at this value throughout the melting period. In other words, it is equivalent in the open-hearth furnace, not to a constant heat input, but to a constant roof temperature and an opaque flame. When the flame is perfectly black, a constant roof temperature implies a constant gross downward radiation in the furnace equal to that of a black body at the furnace roof temperature, since the heat input has to be reduced if the flame is more opaque, in order not to overheat the roof. For a transparent flame the gross downward radiation can be greater than that of a black body at the roof temperature if it is possible to operate with a sufficiently high flame temperature to obtain the safe limiting roof temperature. It is shown in Appendix II that this fact does not affect comparative or qualitative results although it does alter the quantitative results by shortening the absolute time.

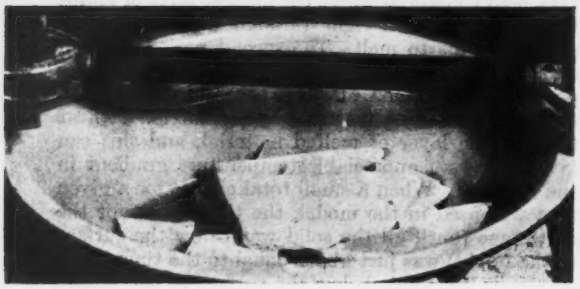
These first qualitative experiments showed that the melting takes place in two stages which can be more or less completely separated. In the first period, unmelted material receives the direct radiation from the flame and melts and runs down to form a pool between the space in the solid matter. During this period relatively little heat is conducted into the body of the charge as a whole since the space between the particles forms a fairly good insulator. The bulk of the heat thus goes into heating the top surface of the material and melting it, except in the case of very heavy material where the highest layer of lumps will become heated right through before their top surface begins to melt. The second period is when all solid material has melted below the surface of the pool which is formed. It then becomes necessary to melt the remaining material by conduction of heat through the layer of melted material, and this can give rise to an appreciable temperature gradient in the material. When a small total charge for a given area was used in the model, the time taken for the first stage (until all the solid was below the surface of the liquid) was just about equal to the time taken to remelt the solids below the surface in the second period. When twice as much material was used, however, the first period took the same length of time but the second period took about four times as long.

These results show, in the first place that, in considering the effect of speed of charging, it is necessary to think not only about the period when the surface of the charge is cold, but about the whole period, including the melting of any solid material below the surface, and it should be borne in mind that conclusions about speeding up the first part can actually be reversed when the second part is taken into account. Secondly, they show how very rapid the first process can be, *i.e.*, that a light material continually melted from the surface gives the fastest possible time for this stage of the process since the heat is being usefully absorbed all the time at the surface without resistance to heat transfer.

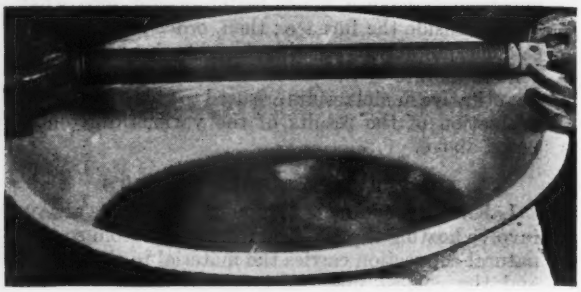
CALCULATIONS BASED ON THE QUALITATIVE MODEL RESULTS

Verification of the Importance of a Superimposed Melted Layer in Retarding Melting of the Remainder

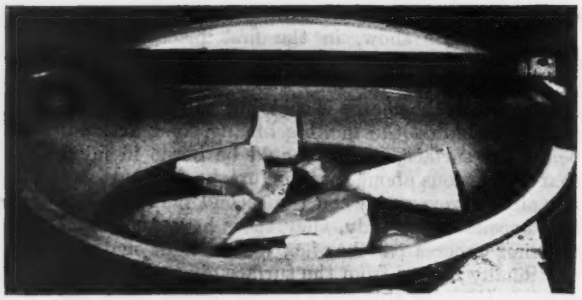
At first sight it might be expected that the difficulty of melting solid material at the bottom of the bath in a steel furnace would be not nearly as great as that of melting solid material at the bottom of a pool of paraffin wax. On the other hand, the thickness of the layer is very much greater in the steel furnace, quite apart from the presence of the slag, and the following calculation shows that under normal conditions conduction through the steel can be a major bottleneck. It was assumed that a bare-steel surface, perfectly black, was receiving gross radiation from a black body at 1675° C. The net heat passing from the surface of the steel was the difference between this gross radiation and the reradiation of the steel at its unknown surface temperature T_1, which could be calculated by equating this net heat to the conduction through the layer of liquid to the solid steel at the bottom, which was taken to be at 1525° C. This layer was assumed to be 20 cm. thick and to have a thermal conductivity of 0·1 cal./cm.-° C.-sec. The rate of melting of the solid steel could also be calculated from the time taken to conduct sufficient heat to it to provide the latent heat to melt a layer 1 cm. thick. This calculation gave a surface temperature of the steel of 1658° C. and a time to melt 1 cm. of 780 sec. Hence the steel surface temperature was only 17° C. below that of the radiator because conduction through the liquid steel was a



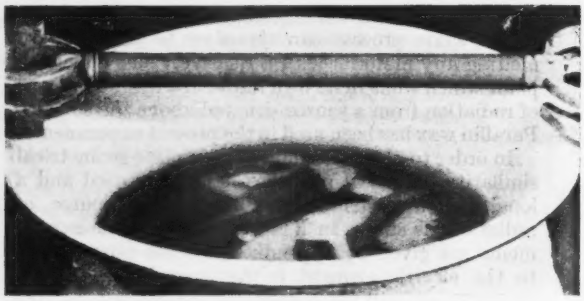
(*a*) First layer in : 2.19 P.M.



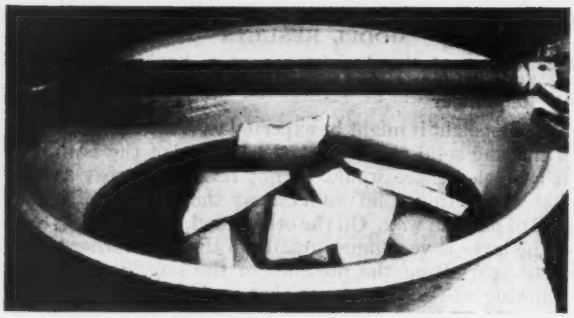
(*b*) First layer beneath surface : 2.31 P.M.



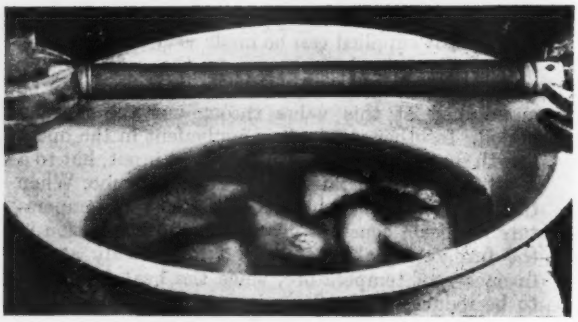
(*c*) Second layer in : 2.31 P.M.



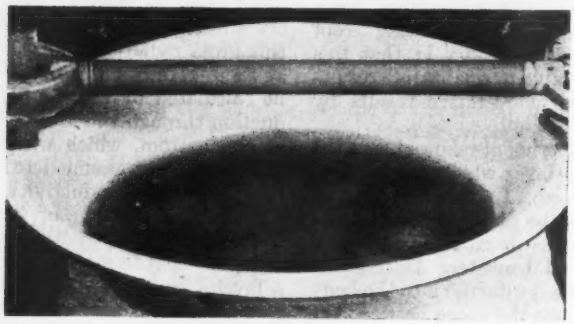
(*d*) Second layer beneath surface : 2.41 P.M.



(*e*) Third layer in : 2.41 P.M.



(*f*) Third layer beneath the surface : 2.47 P.M.



(*g*) Solid layer : 3.0 P.M.

Fig. 1—Layer-charging (3½ oz.) in the wax-melting model

much greater bottleneck than radiation, and the steel surface was reradiating 96·5% of the heat received, whereas if the solid steel at 1525° C. had been at the surface it would have reradiated only 72·6% of the heat received and would have melted 1 cm. in 97 sec., *i.e.*, about eight times as fast.

In actual practice, mixing of the steel by rabbling, boiling, and other processes, provides a convective heat transfer which may increase the thermal conductivity of the layer several times. In spite of this fact, Oliver and Land* have actually found metal within two or three inches of the bottom of the bath to be, on occasions, 50° or even 70° C. below the temperature of the hot metal above it. Moreover, the presence of any slag on the surface gives a layer with a very much lower conductivity. Manterfield has shown a temperature difference of 50° C. across the slag, which is comparable with the difference of 130° C. calculated above for stagnant steel.

This calculation thus indicates that the qualitative model is correct in emphasizing that while it may be possible to accelerate the processes of melting all the charge above the surface by altering the charging process, such an acceleration may be quite a spurious effect as far as the complete melting below the charge surface is concerned. The question then arises, what is the fastest possible melting rate for the steel ?

The Physical Significance of the Shortest Possible Melting Time

Here again, at first sight, it might be considered that the main aim was to maintain dead cold steel at the surface all the time during charging. The model makes clear that this is not the true criterion for the shortest total melting time. One can maintain cold steel at the surface only until all the cold steel has been charged, and it then remains to melt any unmelted material below the surface. Now the time in which the steel is melted must be the time required to provide the total heat of heating and melting by the difference between the gross heat input and reradiation from the steel surface. For a given gross downward heat flow which, as shown in Appendix II, is equivalent to a given roof temperature, this time will therefore have its shortest possible value, as far as alterations in the arrangement of the charge in the bath are concerned, if the integrated reradiation from the steel–slag surface throughout the melting time is a minimum. This in turn implies that *the heat never has to flow through the steel or slag against a finite thermal resistance before reaching the point where it is absorbed as temperature rise*, since such a flow implies a temperature gradient in the steel or slag and hence that the surface is hotter than the point where the heat is being used, so that the reradiation is higher than it need be. Different ways in which this condition can be satisfied and in which the theoretical minimum melting time can be achieved for a given gross downward radiation, are as follows :

(*a*) The whole mass is a perfect conductor so that it heats uniformly throughout.

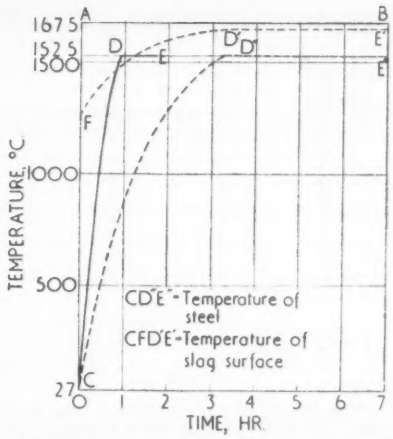


Fig. 2—Comparison of times to heat and melt 12 in. of steel: (*a*) With perfect heat transfer within the steel (solid curve), and (*b*) with slag layer having a resistance equivalent to 10 cm. of steel (broken curves). Linear temperature scale

(*b*) The coldest material is always on the top so that the net radiation flowing into the steel is always absorbed in the top layer.

(*c*) The top layer is thin and perfectly insulated from the rest of the charge. All the net heat is then absorbed by it until it melts and exposes the next layer, which then goes through the same cycle.

These points are illustrated by Figs. 2 to 5, in each of which the line AB represents the gross downward radiation assumed to be independent of time ; CDE represents the curve for the reradiation of the steel if it has perfect thermal conductivity, CD corresponding to the heating period, and DE to the period of supply of latent heat. The curve $CFD'E'$ represents the reradiation of the slag surface if it has a resistance to heat transfer, while $CD''E''$ represents the temperature of the main mass of steel. Figure 2 gives, on a linear time scale, the comparison between the ideal case and the case of a slag resistance equivalent to 10 cm. of steel. Figure 3 is the same comparison plotted on a fourth-power temperature scale, while

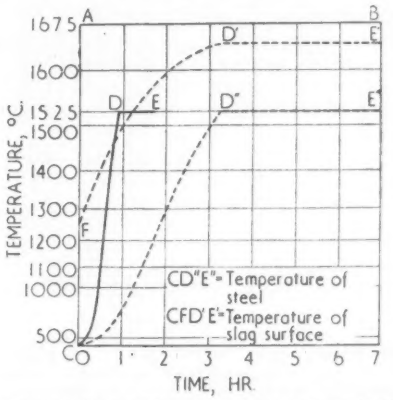


Fig. 3—Comparison of times to heat and melt 12 in. of steel. As Fig. 2, but with fourth-power temperature scale

* D. A. Oliver and T. Land, *Journal of The Iron and Steel Institute*, 1942, No. I, p. 245P.

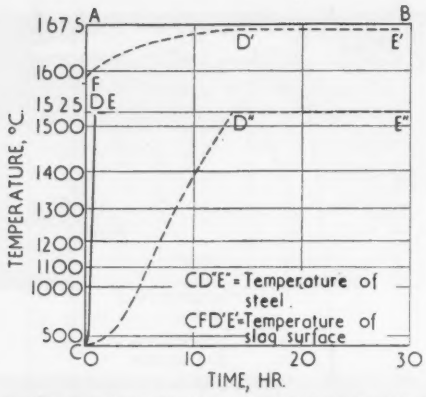


Fig. 4—Comparison of times to heat and melt 12 in. of steel: (*a*) With perfect heat transfer within the steel (solid curve), and (*b*) with slag layer having a resistance equivalent to 50 cm. of steel (broken curves). Fourth-power temperature scale

Fig. 4 compares the ideal case with that of a slag resistance equivalent to 50 cm. of steel, again on a fourth-power temperature scale. In Figs. 3 and 4 radiation is linearly proportional to the abscissa, and since the same amount of heat has to be supplied in each case, the area between *AB* and *CDE* must equal that between *AB* and *CFD'E'* in these figures ; the second case gives a longer time because of the temperature difference through the thermally resisting layer represented diagrammatically by the abscissa difference between the two dotted curves *CFD'E'* and *CD"E"*.

Figure 5 illustrates the use of diagrams of this type to compare two of the three methods of achieving the ideal melting time. Figure 5*a* is the usual case, shown in Figs. 2 to 4, of the whole bath being a perfect conductor so that it all heats up simultaneously. This can be achieved by violent agitation of the bath. Figure 5*b* corresponds to the third condition, in which all the heat first melts a top layer,

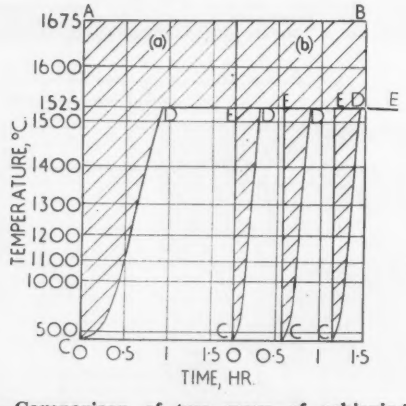


Fig. 5—Comparison of two ways of achieving the theoretical minimum melting time for a fixed gross downward radiation: (*a*) Perfect conductor, melting all at once, and (*b*) three thin layers (each a perfect conductor, but fully insulated from each other) melting in turn

then a second layer, and then a third layer. The total time is the same as the first, since each layer requires a third of the time of the original one. The second condition is not readily plotted because it implies rearranging the order of the three layers as soon as the top one ceases to be the coldest.

Numerical Calculation of the Shortest Possible Melting Time

The calculation of the time required to melt steel under conditions in which the temperature is always equal at any two points of the bath has been carried out by L. Daws (*see* Appendix III) for the case where the gross radiation falling on the steel (black surface) is that from a black body at 1675° C., so that the net radiation is $\sigma(1948^4 - \theta^4)$ cal./sec., where σ is Stefan's constant. This heat flow must be equal to the heat required to produce a rate of temperature rise $d\theta/dt$, given by :

$$sd\rho\frac{d\theta}{dt}$$

where ρ is the density, s is the specific heat, and d is the depth, of the bath. This gives an expression which can be integrated explicitly for the time between the two temperatures.

Assuming the specific heat of the steel to be 0·16, its density 7·85, and σ (Stefan's constant) $1{\cdot}36 \times 10^{-12}$ cal./sq. cm.-sec.-° K.^{4}, and the depth of the bath d to be 30 cm. (12 in.), this gives a heating time of 56 min. The time required to provide the latent heat of 65 cal./g. when the steel is all at a temperature of 1525° C. is 49 min., giving a total time of 105 min. This time can be reduced only by increasing the gross downward radiation (increasing the permissible roof temperature), by reducing the depth of the bath (to which it is directly proportional), or by lowering the flame emissivity. The presence of slag or of any need to provide the heat at a certain depth in the steel rather than at the surface, will represent longer times. The case where the heat has to pass through slag equivalent to 10 cm. of steel (Figs. 2 and 3) corresponds to a heating time of 195 min. and a total melting time of 415 min.

Values of the theoretical minimum melting times for various limiting roof temperatures and depths of bath are as follows :

Theoretical Minimum Melting Times (in minutes) for Various Roof Temperatures (θ_1') and Depths of Bath (d) (Cold Charge)

θ_1, °C.	d = 6 in. (15 cm.)	d = 12 in. (30 cm.)	d = 18 in. (46 cm.)	d = 24 in. (61 cm.)
(a) *Perfectly Opaque Flame*				
1550	233	468	701	936
1600	94	193	288	385
1650	66	132	197	263
1700	51	102	153	204
1750	42	83	125	167
(b) *Flame of Emissivity ½* with Sufficient Heat Input Always to Maintain the Roof at θ_1*				
1550	133	268	400	535
1600	54	110	165	220
1650	38	75	113	150
1700	29	58	88	117
1750	24	47	71	96

* *See* Appendix II

The Case where there is Insufficient Heat to Keep the Roof up to Temperature

In any actual furnace it is not possible to introduce and burn fuel so fast that the roof is kept up to temperature after a cold layer of charge has been placed all over the bath, hence the question arises as to whether it is better to charge successive batches so as to cover the whole of the surface, or to charge smaller amounts over only one-half or one-third of the surface and not reduce the roof temperature. The arguments developed in the preceding section enable this question to be answered. Clearly, the first charge must be inserted so as to cover the whole bath surface, since any area uncovered means a loss of useful heat absorption. On the other hand, subsequent to this time, charging should proceed, ideally, in such a way as never to cool the roof, since such cooling means that the time AB in Figs. 3, 4, and 5 is no longer straight but has ' saw teeth ' below the present line, implying that to obtain the same area between the steel-surface temperature curve and the AB curve a greater time will be required.

QUANTITATIVE MODEL RESULTS

Since the foregoing calculations on the importance of a superimposed melted layer show that the model correctly assesses the dual process of melting the exposed solids by direct radiation and of subsequently melting the submerged solids by conduction through the overlying molten layer, it was decided to check the theory developed in the previous section by further comparative tests on the model. In the first series of comparative tests (*see* Appendix I) three units were operated simultaneously with identical charges and radiation, but one was charged all at once, the second in three equal quantities, and the third in five equal quantities. In the two latter cases the subsequent charges were inserted when the previous one was melted below the surface but not right through. These three were shown to give total times for melting all the wax which had no significant difference. This confirms that overall speed of melting is not governed by the speed with which the charge can be placed in the furnace.

To confirm that the speed of melting is, for a given gross downward radiation, governed by the extent to which the heat has to be forced through a thermal resistance, a second series of trials was carried out.

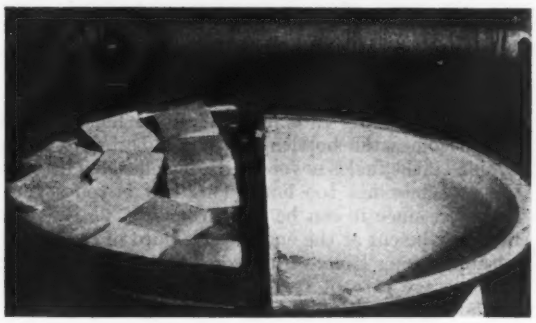


Fig. 6—Continuous charging in the wax-melting model; primary charging before heating

In these the first arrangement was charging the usual weight in three lots, using, however, thin flake material about one-quarter as thick as the previous one. The second arrangement was the standard material charged in three lots, and the third was the standard material charged continuously in a single layer on to a sloping surface covering one-half of the bath, as shown in Fig. 6. In this the radiation element was moved upwards so as to be as far from the sloping surface as it was from the base of the dish in the other cases, hence only this half of the surface was effective for melting, the other half of the dish acting purely as a storage space for the molten wax. Both the first and the third arrangement in this second series of trials gave a melt in about 25% less time than the standard one ; this seems to confirm the idea fully, since the thin flake material is a fair approximation to the third way of achieving the ideal of no thermal resistance given in the previous section, and the sloping surface gives an approximation to the first, since the material is always melted in a thin layer.

CONCLUSIONS

The Need to Assess Methods of Charging by the Effect on the Total Time of Melting

The discussion of the preliminary experiments shows that in any assessment (whether by theoretical arguments or by experiments) of the relative merits of different methods of charging, it is necessary to assess the effect of the alterations upon the period required for complete melting of the charge, which may often be the reverse of the effect upon the charging period alone. This is because the speed at which the charge can be passed into the furnace depends upon the melting of the higher parts of the charge, and it does not include the time to melt the solid mass which forms at the bottom of the bath. If the charging time is adjusted according to a ' Plimsoll line,' then an increase in the average period* will produce a reduction both in the charging time (because room is made for the next batch more rapidly) and in the total time of melting (because heat is pumped into the bath more rapidly†). Hence in this case the charging and total melting times are subject to the same arguments. However, in the case where alteration of the materials charged, or the order of charging, is in question, wrong conclusions can be drawn from arguments based upon the melting of the projecting part of the charge alone. This is illustrated by the experiments described in Appendix I, which show one case in which inserting all the charge simultaneously gives a total melting time no different from that in which it is put in over a considerable period.

The Ideal Melting Rate

The most important conclusion is therefore that differences between methods of charging arise from the extent to which they cause deviation from the

* For example, by increasing the maximum fuel-supply rate or flame-supply rate so as to cause a reduction in the time when the roof is below the safe limiting temperature, or by using a new brick which allows the safe limiting temperature of the roof to be raised.

† I. D. L. Boswell and M. W. Thring, *The Iron and Steel Institute*, 1946, *Special Report No.* 37, Fig. 11, p. 20.

ideal melting rate which occurs when the two following conditions are satisfied :

(1) The roof is maintained at the safe maximum temperature the whole time.

(2) The heat absorbed in the charge never has to pass through a thermal resistance. This implies that either (*a*) the mass has so high a thermal conductivity that its temperature is uniform throughout, (*b*) the coldest material is always at the top, or (*c*) the mass is divided into thin layers perfectly insulated from one another so that all the heat is absorbed in the top layer.

Deviations from the Ideal Due to Limited Heat Input

Condition (1) above rules out any charging method which causes excessive cooling of the furnace, and since almost any method of charging in large batches does cool the roof below the safe maximum, it implies that ' little and often ' is better than large batches. In fact, the optimum size of batch is that with which the roof can just be kept at the safe maximum temperature when fuel is being burnt in the furnace at the maximum possible rate. The optimum time between such batches or the optimum rate for completely continuous charging (*i.e.*, pans at equal intervals throughout the charging period) is governed by the need to satisfy condition (2), as discussed below.

Deviations from the Ideal Due to Thermal Resistance in the Charge

Broadly, condition (2) implies that the more of the charge which can be melted while it is on top, the better, and that any slag on the surface during melting is a great disadvantage. Hence the condition means that the slag-forming materials should be inserted as late as possible (if steelmaking considerations would allow any alterations of this factor), and that the ideal arrangement of the charge is with light ' pillars ' or light scrap underneath holding up the heavier materials so that the latter are directly melted by heat from the top. It implies also that the charging of pig and other materials on to the furnace banks, where they melt and run down into the bath, is a very sound method.*

Light and Heavy Scrap

As far as the satisfaction of this second condition is concerned, there is no reason why a light material should melt more slowly than a heavy one ; indeed the light material is likely to give a closer approximation to the ideal than the heavy one. This follows because the radiation gap between successive layers of a light material is a better insulator than the solid steel in a heavy material, and hence more of the heat supplied to the top surface will be used in heating and melting the top layer in the former case than in the latter, where deeper parts of the bath will be heated simultaneously by heat which is conducted from the top surface. This is made clear by considering the extreme case of thin layers of steel separated by perfect insulation. Here each layer will be heated and melted at the same temperature as the top surface because each layer is thin ; this layer then runs down and exposes the next one, which goes through the same cycle. At no time, therefore, is the surface reradiating more than the essential minimum, and condition (2) is exactly satisfied. This conclusion is confirmed by the experiments on light material described in Appendix I.

Light scrap is, of course, disadvantageous in the open-hearth furnace for reasons connected with its extreme bulk—the number of pans necessary to charge it is greatly increased and it is necessary either to use a charger all the time or to fill the furnace to a much higher level since the specific volume rises from about 5 cu. ft./ton for solid steel to 50 cu. ft./ton for light scrap. These factors appear to correspond more to inconvenience than to reduced throughput.

The Rate of Charging

The analysis has shown that the *total* melting time (as opposed to the charging time) is related to the speed with which the charge is inserted into the furnace only when either (i) the charge is inserted too fast, causing excessive cooling and so reduction in the gross downward heat flow so that the heat-transfer bottleneck is made even worse ; or (ii) the charge is inserted so slowly that in fact all the useful melting which can be done on the charge already in, has been done and the furnace is being held—a condition which would correspond, for example, to the second instalment of charge in Fig. 5*b* not being put in until some time after the first has been fully melted at 0·6 hr.

To draw practical conclusions from this theoretical examination of the problem it is necessary to lay down criteria by which these conditions can be distinguished. A simple test for the first condition is the roof-pyrometer chart ; *ideally, charging would proceed uniformly at such a rate that the latter was always just below the maximum safe value when the fuel was being burnt at the maximum rate.* More practically, if the roof pyrometer drops below a certain minimum temperature, say, 1400° C., then the charge is being put in too fast.

As regards the second possibility (charging so slowly that the charging rate instead of the heat-transfer rate becomes the bottleneck) this is certainly being avoided if the fuel is never cut during charging because the roof becomes too hot. This test is too severe, however, since it can be seen from Fig. 5*b* that the fuel may be cut at the end of each third of the charge without losing time. The exact test is clearly that the average rate of fuel input through the melting period does not fall below the highest possible average rate ; from Figs. 5*a* and 5*b* it does not matter whether the high rate is attained with all the fuel cuts at the end of the melting period or with some earlier cuts.

* This argument can be extended to the suggestion that the ideal shape for the open-hearth bath is not with a uniform depth, but with shallow sloping sides and a deep well in the centre. Such an arrangement would give a rapid melting rate if the material were continually charged on to the sloping banks and ran down to the well, as in experiment (*c*) of the second test in Appendix I, but it would not of course be very suitable for refining the steel, and oxide would cause cutting of the banks. For pure melting processes a furnace consisting of a hearth on to which the material is charged, sloping down to a removable well or ladle and fired by a flame passing in counterflow to the liquid steel over the ladle and leaving at the charging end, would represent a good approximation to the thermodynamic ideal.

This test is, of course, difficult to apply in practice, but where the more stringent test, that the fuel shall never be cut until all the charge is in is applied, then it is clear that the charging rate is adequate.

Application of these tests to furnaces which are equipped with fuel-flow and roof-temperature recorders would reveal the extent to which increase in the possible charging rate is desirable—it seems likely that in nearly all cases the charging must in fact be interrupted for appreciable periods because the heat-transfer rate is the bottleneck. The chief exception is where a physical hold-up of the materials to the charger occurs.

It should be pointed out that, in the theory, it has been assumed that the charge can always be inserted over the whole bath simultaneously. The fact that this cannot be attained in practice does mean that acceleration of the putting in of a very thin layer of the first charge over the whole surface can be advantageous.

Appendix I

WAX-MELTING EXPERIMENTS

By J. P. Simons

Description of Apparatus

The essential part of the apparatus is a pencil-type electric heating element, 7 in. long, suspended 3 in. above the bottom of an elliptical piedish, of overall dimensions $10\frac{1}{8} \times 7\frac{3}{4} \times 2\frac{3}{8}$ in.

Three comparisons were carried out simultaneously, the heating elements being connected in parallel. An ammeter and a 'Variac' auto-transformer were included in the circuit to keep the wattage constant at a value of 525 watts, and the apparatus was screened from convection currents by Bristol boarding.

Description of Each Experimental Procedure

In all cases the baths were heated for 10 min. before charging commenced. With layer-charging, each layer was charged when the preceding layer had sunk beneath the surface of the liquid wax formed in the bath. Each experimental charging arrangement was carried out under all three elements in turn, so that differences between the three elements were averaged out.

In the first statistical test the three comparisons consisted of:

(a) *Bulk Charge*—10 oz. of paraffin wax, 2 in. square, ¼ in. thick, charged into the dish all at once.

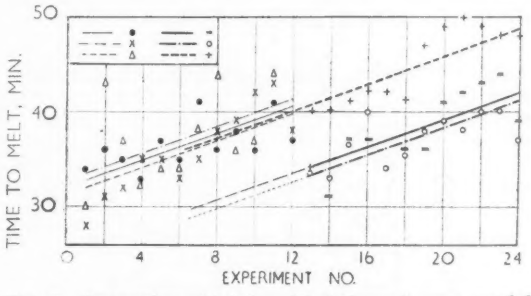


Fig. 7—Correction of total melting times in wax-model trials for change of apparatus with use

(b) *Three-Layer Charge*—10 oz. of paraffin wax, 2 in. square, ¼ in. thick, charged in three $3\frac{1}{3}$-oz. layers.

(c) *Five-Layer Charge*—10 oz. of paraffin wax, 2 in. square, ¼ in. thick, charged in five 2-oz. layers.

The melting times of the three comparisons were as follows:

	Melting Time, min.		
	(*a*)	(*b*)	(*c*)
(1)	34	28	30
(2)	36	31	42
(3)	35	32	37
(4)	33	35	33
(5)	37	35	35
(6)	35	33	34
(7)	41	35	38
(8)	36	38	44
(9)	38	39	36
(10)	36	42	37
(11)	41	43	44
(12)	37	38	40
Averages	36·6	35·8	37·5

The three comparisons of the second statistical test consisted of:

(a) *Flake Charge*—10 oz. of paraffin wax in flakes, charged in three $3\frac{1}{3}$-oz. layers.

(b) *Three-Layer Charge*—10 oz. of paraffin wax, 1 in. square, ¼ in. thick, charged in three $3\frac{1}{3}$-oz. layers.

(c) *Tray Charge*—10 oz. of paraffin wax, 1 in. square, ¼ in. thick, charged continuously on to a tilted brass tray occupying half the bath area. The wax was charged so as to keep the tray covered, and the molten wax was allowed to run down a slope extending to the bottom and thus to occupy the other half of the bath. A metal strip was used as a guard above the slope to prevent unmelted material from slipping over the edge. The element was raised in this case so that it should be the standard height above the essential melting area.

The melting times for the three comparisons of the second statistical test were as follows:

	Melting Time, min.		
	(*a*)	(*b*)	(*c*)
(13)	34	40	34
(14)	31	40	33
(15)	37	41	37
(16)	37	42	40
(17)	37	42	34
(18)	36	41	36
(19)	36	47	38
(20)	41	49	39
(21)	42	50	38
(22)	43	49	40
(23)	44	48	40
(24)	39	48	37
Averages	38·1	44·8	37·2

Elimination of Effects Due to Change in Heating Element

As the other experimental conditions were constant, the creep observed in the melting times must be assumed to be due to a change in the fraction of the heat input to the elements which is radiated; thus slackening of the Nichrome wire and oxidation of the surface decreases the radiation and increases the amount of heat by convection. The effect was allowed for in the following way. Curves of 'time-to-melt' against 'number of experiment' were plotted (Fig. 7), regression lines were drawn and then redrawn so as to have their gradients equal to the mean gradient of the regression lines. The new lines were found to be well within the probability error of the regression lines.

The actual averages for the trials together with the averages for the second three trials corrected back twelve trials, using the mean slope, were as follows :

First Series			Second Series			Second Series (Corrected)		
(a)	(b)	(c)	(a_1)	(b_1)	(c_1)	(a_1)	(b_1)	(c_1)
36·6	35·8	37·5	38·1	44·8	37·2	30·4	37·0	29·5

When corrected in this way the differences between trials (a), (b), (c), and (b_1) are shown to be not significant, while trials (a_1) and (c_1) are significantly shorter than the rest.

Appendix II

MAXIMUM DOWNWARD RADIATION OBTAINABLE WITH A GIVEN ROOF TEMPERATURE

In order to approximate to the actual radiation conditions existing in the open-hearth furnace it is necessary to know the value of the gross downward radiation falling on the slag–steel surface. Since, in the present paper, the aim is to assess, not the relative merits of different combustion conditions, but those of different charging schedules, the flame can be taken to have the limiting safe value corresponding to the roof not being overheated. The case where excessively fast charging cools the roof is regarded as a deviation from this ideal and is discussed on page 218 ; the present objective is to calculate the maximum possible downward radiation obtainable when the roof is at its maximum temperature for any given steel surface temperature. The equations for heat flow (Thring*) are :

$$\text{Net heat to roof} = R_f + \sigma(1 - e)T_S^4 - \sigma T_R^4$$

$$\text{Gross downward radiation (DHF)} = R_f + \sigma(1 - e)T_R^4$$

where R_f = flame radiation
e = flame emissivity
σ = Stefan's constant
T_S = slag surface temperature
T_R = roof surface temperature.

If the conduction through the roof is neglected, as discussed by Thring, the net heat to the roof can be equated to zero so that :

$$R_f = \sigma T_R^4 - \sigma(1 - e)T_S^4$$

Hence we can eliminate R_f, as long as sufficient R_f is provided to maintain T_R. This gives :

$$\text{DHF} = \sigma(T_R^4(2 - e) - (1 - e)\,T_S^4) \quad \ldots\ldots\ldots\ldots(1)$$

$$\text{Net heat to slag and steel} = \text{DHF} - \sigma T_S^4 = \sigma(2 - e)\,(T_R^4 - T_S^4) \quad \ldots\ldots(2)$$

These expressions show that when the flame is perfectly opaque, so that $e = 1$, then the maximum possible downward radiation (DHF), is equal to the radiation from a black body at the maximum allowed roof temperature T_R, and the net heat corresponds to radiation interchange with a black body at T_R. The physical meaning of this is that when $e = 1$ the roof can only 'see' flame and hence flame and roof must be in equilibrium and flame radiation must be at the roof temperature.

When, however, e is less than 1, the roof is partly cooled by radiation through the flame to the charge and the flame can be hotter for the same roof temperature—in the extreme case with a perfectly transparent flame the net heat to the steel would be twice as great, but it would not in fact be possible to maintain the roof temperature, hence there is an optimum flame emissivity from the point of view of the minimum melting time. From the point of view of fuel economy the perfectly black flame is, of course, the best.

At first, the dependence (equation (1)) of the downward heat flow upon the slag surface temperature would appear to make the calculation of the minimum melting time considerably more complicated. Equation (2) shows, however, that the final result is merely equivalent to changing the temperature scale in the ratio $\sqrt[4]{2 - e} : 1$ and the time is accordingly reduced by the factor $1/(2 - e)$. Hence a very transparent flame (e very small)—if sufficient heat could be obtained with such a flame to keep the roof up to temperature—would give one-half the times calculated in the previous section. The fuel requirements would of course be considerably higher. Part of the data on p. 216 is calculated for the case of a flame of overall emissivity 0·25, assuming that sufficient heat can be inserted to attain the limiting roof temperature all the time.

Appendix III

CALCULATION OF TIME REQUIRED TO HEAT AND MELT STEEL IN OPEN-HEARTH BATH

By L. Daws, B.Sc.

Free Steel Surface

It is assumed, in the theory, that steel is a perfect conductor of heat. Suppose that the roof has an equivalent black-body radiation temperature of θ_1° K. When the bath is at θ° K., the rate of heat flow to it per unit area, assuming the bath is a black body, is :

$$\sigma(\theta_1^4 - \theta^4)$$

where σ is Stefan's constant.

If the density of the bath is ρ, the depth d, and s the specific heat, the rate of heating of the bath is :

$$\rho s d \frac{d\theta}{dt}$$

where all values are in c.g.s. units. Therefore :

$$\sigma(\theta_1^4 - \theta^4) = \rho s d \frac{d\theta}{dt}$$

If the initial temperature of the steel is taken as 27° C., the time t to heat it to θ° K. is given by :

$$t = \frac{\rho s d}{\sigma} \int_{300}^{\theta} \frac{d\theta}{(\theta_1^4 - \theta^4)}$$

i.e.,

$$t = \frac{\rho s d}{4\sigma\theta_1^3} \int_{300}^{\theta} \left[\frac{1}{(\theta_1 + \theta)} + \frac{1}{(\theta_1 - \theta)} + \frac{2\theta_1}{(\theta_1^2 + \theta^2)} \right] d\theta$$

$$= \frac{\rho s d}{4\sigma\theta_1^3} \left[\log_e \left(\frac{\theta_1 + \theta}{\theta_1 - \theta} \right) + 2 \arctan \frac{\theta}{\theta_1} \right]_{300}^{\theta}$$

* *The Iron and Steel Institute*, 1946, *Special Report No.* 37, p. 176.

$$= \frac{\rho s d}{4\sigma\theta_1^3}\left[\log_e \frac{(\theta_1+\theta)(\theta_1-300)}{(\theta_1-\theta)(\theta_1+300)} + 2\arctan\frac{\theta}{\theta_1} - 2\arctan\frac{300}{\theta_1}\right] \quad \ldots\ldots(1)$$

Now suppose a latent heat of 65 cal./g. is needed at 1800° K. to melt the steel. Then an amount of heat 65 ρd cal. per unit area of the bath is required to melt the steel. Since the rate at which the surface receives radiant energy is $\sigma(\theta_1^4 - 1800^4)$, the time T to melt the steel is given by :

$$65\rho d = \sigma(\theta_1^4 - \theta^4)T$$

i.e.,

$$T = \frac{65\rho d}{\sigma(\theta_1^4 - \theta^4)} \quad \ldots\ldots(2)$$

If the value of t obtained by putting $\theta = 1800°$ K. in equation (1) is t_1, then $(t_1 + T)$ is the total time required to heat and melt the steel.

Total times were calculated from the expressions obtained in equations (1) and (2) for values of θ_1 and d specified on page 216 and for $\rho = 7{\cdot}85$ g./c.c., $s = 0{\cdot}16$ cal./g.-° C., $\sigma = 1{\cdot}36 \times 10^{-12}$ cal./sec.-sq. cm.-° K.

In Figs. 2, 3, and 4 the solid curve *CDE*, representing the temperature of the bath as a function of time, was obtained from equations (1) and (2), assuming the values given above for ρ, s, and σ, and taking $d = 30$ cm. and $\theta_1 = 1675°$ C.

With Resistive Surface Layer of Slag

In the following theory it is assumed that (*a*) the slag has no heat capacity, and (*b*) the steel is a perfect conductor. Let the roof have an equivalent black-body radiation temperature θ_1° K. Then, rate of radiant heat transfer to the slag is $\sigma(\theta_1^4 - \phi^4)$, where ϕ is the slag surface temperature at time t.

If K cal./sq. cm.-sec.-° C. pass through the slag layer, then from assumption (*a*) the rate of heat transfer through the slag is $K(\phi - \theta)$, where θ° K. is the temperature of the slag–steel interface. Further, from assumption (*b*) the rate of heating of the steel is :

$$\rho s d\frac{d\theta}{dt}$$

Then

$$\sigma(\theta_1^4 - \phi^4) = K(\phi - \theta) \quad \ldots\ldots(3)$$
$$= \rho s d\frac{d\theta}{dt}$$

Differentiating relation (3) with respect to time

$$-4\sigma\phi^3\frac{d\phi}{dt} = K\frac{d\phi}{dt} - K\frac{d\theta}{dt} \quad \ldots\ldots(4)$$

But

$$\frac{d\phi}{dt} = \frac{\sigma K}{\rho s d}(\theta_1^4 - \phi^4)$$

Therefore from equation (4) :

$$(K + 4\sigma\phi^3)\frac{d\phi}{dt} = \frac{\sigma K}{\rho s d}(\theta_1^4 - \phi^4)$$

If $\phi = \phi_1$ at $t = 0$, then time t required to raise the surface temperature of the slag from ϕ_1 to ϕ is given by :

$$\int_{\phi_1}^{\phi}\left(\frac{K + 4\sigma\phi^3}{\theta_1^4 - \phi^4}\right)d\phi = \frac{\sigma K}{\rho s d}t$$

i.e.,

$$t = \frac{\rho s d}{K\sigma}\int_{\phi_1}^{\phi}\left[\left(\frac{K}{2\theta_1^2(\theta_1^2 + \phi^2)} - \frac{2\sigma\phi}{\theta_1^2 + \phi^2}\right) + \left(\frac{K}{4\theta_1^3} - \sigma\right)\frac{1}{\theta_1 + \phi} + \left(\frac{K}{4\theta_1^3} + \sigma\right)\frac{1}{\theta_1 - \phi}\right]d\phi$$

i.e.,

$$t = \frac{\rho s d}{4K\sigma\theta_1^3}\left\{2K\arctan\frac{\phi}{\theta_1} - 2K\arctan\frac{\phi_1}{\theta_1} + K\log_e\frac{(\theta_1+\phi)(\theta_1-\phi_1)}{(\theta_1-\phi)(\theta_1+\phi_1)} + 4\sigma\theta_1^3\log_e\left(\frac{\theta_1^4 - \phi_1^4}{\theta_1 - \phi^4}\right)\right\} \quad (5)$$

The initial temperature of the steel was taken as 300° K. Thus the quartic in ϕ (*see* equation (3)) determines ϕ_1.

When $\phi = 1800°$ K., the steady melting state commences. The value of slag surface temperature during this stage is fixed by equation (3). Let its value be ϕ_2. Then, to melt a depth d of steel, the time required T is given by :

$$K(\phi_2 - 1800)T = 65\rho d$$

i.e.,

$$T = \frac{65\rho d}{K(\phi_2 - 1800)} \quad \ldots\ldots(6)$$

65 cal./g. being the latent heat of steel assumed. Using equations (3), (5), and (6), θ and ϕ were evaluated in parallel in the ranges $\theta = 300$ to 1800° K., $\phi = \phi_1$ to ϕ_2, assuming the same values for ρ, s, d, σ, and θ_1, as above.

The values obtained for θ and ϕ have been plotted against time in Figs. 2, 3, and 4. The values taken for K were $0{\cdot}01$ cal./sq. cm.-sec.-° C. (*see* Figs. 2 and 3) and $0{\cdot}002$ cal./sq. cm.-sec.-° C. (*see* Fig. 4), corresponding respectively to slag resistance equivalent to depths of steel of 10 cm. and 50 cm.

FORTHCOMING B.I.S.R.A. PAPERS

The following papers, received from the British Iron and Steel Research Association, have been accepted for publication and will appear in forthcoming issues of the *Journal*:

"*Studies on Anti-Fouling Compositions—Pt. VI*," by H. Barnes.

A further paper in this series, dealing with the leaching rate during the early stages and its relation to surface conditions in cuprous oxide compositions.

"*Plastic Strain and Hysteresis in Drawn Steel Wire*," by R. S. Brown.

Reviews forms of test applicable to wire and gives details of stress/strain characteristics at loads approaching the ultimate tensile strength.

"*The Acceleration of the Rate of Isothermal Transformation of Austenite*," by M. D. Jepson and F. C. Thompson.

The paper describes the effect of stress on the rate of isothermal transformation over a range of temperatures.

An Electrical Pressure Meter for the Measurement of Open-Hearth-Furnace Differential Pressures

By S. S. Carlisle and B. O. Smith

SYNOPSIS

The paper describes a sensitive electrical differential-pressure meter developed in the Physics Laboratories of the British Iron and Steel Research Association for measurement of open-hearth-furnace differential pressures (0 to $\pm$ 0·1 in. W.G.). The design and construction of the instrument is such that it can be installed close to the measuring point on the roof of the furnace; thus, the errors normally arising from buoyancy effects in long pressure pipes are eliminated. It is specifically designed for remote indication, the pressure differential being measured in terms of an electrical current, which can be indicated or recorded on a normal moving-coil meter situated at any distant position.

The operating principle is that the force on a freely mounted diaphragm, resulting from the applied differential pressure, is automatically balanced by the force developed by a current-carrying coil moving in a fixed magnetic field. At equilibrium the current in the coil is a direct measure of the force produced, and thus of the applied pressure. This 'null' method of measurement ensures a high stability of calibration of the instrument, and freedom from wander of the zero reading.

Introduction

THE open-hearth furnace has, in recent years, been the subject of a great deal of investigation into methods of control and operation of the process; investigation which might be expected to result in increased output, efficiency of fuel consumption, and greater consistency in the quality and characteristics of the product.

Generally speaking the desirable operating conditions of the furnace are those in which as much heat as possible is generated in the furnace chamber, with reasonably efficient fuel combustion, and in which the maximum proportion of this heat is transferred to the bath. The heat which can be generated within the furnace is, of course, subject to the overriding limitation of the temperature at which the roof refractories can be operated. The main factors governing the transfer of heat to the bath have been studied in considerable detail,[1, 2] and it is fairly well established that the flame temperature, flame emissivity, roof temperature, flame path, and nature of surface of the charge are of paramount importance.

These parameters are in themselves dependent, to varying extents, on the controllable operating conditions of the furnace, such as roof temperature, furnace differential pressure, and air/fuel ratio, etc. The benefits to be gained from proper measurement and control of these main variables are discussed in detail in a recent paper by Rogers,[3] and although there is some difference of opinion on the relative importance of the pressure within the working chamber of the furnace, it is generally admitted that, with existing furnace designs, this parameter does exert an appreciable control over furnace performance. Excessive furnace pressure results in flame blowout through doors and cracks in brickwork, with consequent damage to door frames and surrounding refractory material, whereas a too-low furnace pressure results in cold air being drawn in through gaps in furnace doors, thereby cooling the flame. Experiments have shown that air infiltration through doors and leaks in furnace structure can be twice as much as that entering by the air valves. Furthermore, air entering the furnace other than through the air-ports not only affects fuel combustion in an uncontrollable manner, but also makes it very much more difficult to check combustion conditions from an analysis of flue-gas composition.

Leckie[4] has shown that the optimum operating conditions as regards furnace pressure are achieved when the position of the zero pressure level (pressure difference between inside and outside of furnace) is only a few inches above the sill. If, as is usual, the furnace differential pressure is measured at a point at the roof crown, and due allowance is made for the buoyancy effect of the hot gas column within the furnace, an indicated pressure of about + 0·1 in. W.G. is required at this point to satisfy the conditions of zero pressure at sill level in furnaces of average size.

It is found, however, that considerable discrepancies occur in the figures quoted as the optimum operating values of roof pressure determined from experience in different furnaces and melting shops. These differences can, no doubt, be partly accounted for by varying conditions of furnace operation and characteristics of ancillary plant. It seems that in many cases the figures quoted are not the true differential pressures existing at the furnace roof, but are subject to correction for a 'stack' effect caused by a difference in level between the pressure meter and the measuring point at the roof, in conjunction with temperature gradients along the pressure pipes linking the meter with the measuring point. The correction which may be necessary in practice could be as much as 0·06 in. W.G. for a normal disposition of the pressure recorder relative to the furnace.

It is clear that if a reasonable comparison is to be made between the varying conditions of furnace operation, with a view to defining more precisely the optimum working conditions, it is desirable that the admittedly important roof-pressure measurement should be a true one, and not subject to variation with location of the pressure recorder and with the

Project AA/184/48 of the Open-Hearth Instruments Sub-Committee of the Steelmaking Division of the British Iron and Steel Research Association, received 8th December, 1948. The views expressed are the authors' and are not necessarily endorsed by the Sub-Committee as a whole.

temperature conditions of the intervening run of pressure piping.

THE DEVELOPMENT OF THE ELECTRICAL PRESSURE METER

The problem of true measurement of furnace differential pressure was considered by the Open-Hearth Instruments Sub-Committee of the British Iron and Steel Research Association, and the Physics Department was asked to investigate the design of an instrument which would eliminate the errors arising from buoyancy effects in the coupling pipes, if possible, without requiring the installation of long runs of differential-pressure piping. It was suggested that the problem might be solved by fitting one of the standard pressure-measuring instruments close to the measuring point on the furnace roof, connecting it to a horizontal pipe only, and providing for remote indication of the instrument readings.

Although a number of methods have been developed commercially for remote transmission of the indications of differential-pressure-measuring instruments, they are mostly suitable for use only with pressure meters operating on a somewhat higher range than the $\pm 0{\cdot}1$ in. W.G. required for roof-pressure measurement. Furthermore, the instruments that are capable of remote indication of very small pressure differentials did not seem suited to use under the rather severe conditions encountered by an instrument on, or near, the roof of an open-hearth furnace.

It was felt that in this particular case attention should be given to the development of an instrument specifically designed for this application, rather than concentrate effort on the development of an alternative technique for remote indication applicable to existing instruments. It should be an instrument suitable for location on, or near, the roof of a furnace, and its performance must be unaffected by the ambient temperature conditions experienced there.

The method to be adopted for transmission of the instrument readings was given careful consideration, especially in the light of the difference of opinion on whether pneumatic, electric, or hydraulic means are the most suitable. In general, electric transmission was preferred for distant indication of meter readings, provided that special precautions have not to be taken over the characteristics and method of running of the cables, and that its adoption does not entail increased complexity in the design of the sensitive portions of the measuring equipment. In this particular application electrical transmission was also preferred because electrically operated signals have certain advantages when linking the instrument with a controller. This applies, especially if cascaded control is contemplated, where unit controllers are to be interlinked according to some definite relationship. The suitability of the instrument for incorporation in an automatic control system is of particular importance in this application, since a great deal of work is at present being done in applying automatic controls to the open-hearth furnace. The automatic control links, on which work is at present being concentrated in the industry, are: (*a*) automatic control of roof temperature by operation of the fuel-valve input, (*b*) automatic control of the roof pressure by operation of the flue damper, and (*c*) automatic control of the air/fuel ratio.

Experience indicates that these factors are interdependent and, ultimately, controllers cannot be considered as completely separate units but must be capable of interrelation in order to preserve stability of operation. As mentioned earlier, control functions in an electrical form lend themselves to such interrelation, as voltages or currents can be added and subtracted so readily. Since roof-temperature measurements are already necessarily in an electrical form, to maintain uniformity it is justifiable to indicate roof-pressure also by an electrical signal.

The principle normally employed for the measurement and recording of small differential pressures requires a measurement of the displacement of a diaphragm against a restraining spring, or the extent of unbalance of 'floating bells' attached to the ends of a weighbridge arm, the 'bells' being connected to the atmosphere and to the pressure source being measured. These simple deflectional methods do not readily lend themselves to remote indication because of the difficulties of devising suitable elements to transmit the small displacements resulting from the small actuating forces available. Furthermore, the constancy of calibration of such a simple deflectional system is dependent upon the stability of the restraining spring characteristics, and distortion of the frame of the measuring head, which might result from thermal expansion, can give rise to drifts in the zero setting.

Many of the disadvantages of these deflectional methods are overcome by the adoption of a null technique of measurement. The principle of operation is that the force or quantity to be measured is automatically balanced by an equal but opposing force, which can be generated accurately proportional to some other physical quantity, the value of which, at the equilibrium condition, is then taken as a measure of the unknown force. The best example of this null system of measurement in electrical measurements is the simple potentiometric method of measuring e.m.f.

Some pressure-measuring instruments, operating on this principle and capable of remote indication, are now on the market. For example, one such instrument magnifies the pressure to be measured by reproducing it as an air pressure at a higher level.[5] By applying the initial pressure to be measured to a sensitive diaphragm a force is produced which is balanced on a weighbridge arm against the force generated by application of a higher level of air pressure to a small diaphragm. This balancing pressure is automatically adjusted by a flapper and nozzle device until the weighbridge arm reaches equilibrium. The higher-value pneumatic pressure is then available as a direct measure of the initial small pressure, and can be remotely indicated through a run of pressure piping coupled to a simple indicating, or recording, pressure meter.

The instrument described in this report makes use of a null system in which balance is effected electrically. This permits a design in which sensitive precision pivots and levers are not necessary, thus giving a much simpler, neater, and more robust

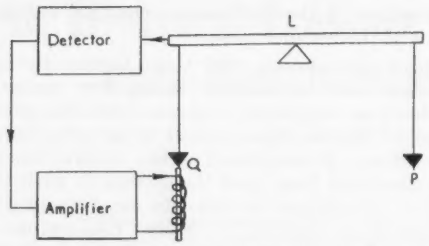


Fig. 1—Schematic diagram of an automatic current balance for force measurement

mechanical construction than can be achieved by other techniques, while still preserving high stability of calibration, freedom from zero wander, and the facilities attendant with electrical remote indication of instrument readings.

THE ELECTRICAL-NULL-BALANCE TECHNIQUE FOR MEASUREMENT OF PRESSURE

The electrical pressure meter described in this paper makes use of a null technique in which the balancing force is produced electrically. The principle of operation can best be described as an automatic version of the original current balance, except that a force is measured in terms of a current instead of the reverse, as was the case with the current balance.

Referring to Fig. 1, the force to be measured, P, is applied at one end of a weighbridge arm with a fulcrum at L. A balancing force, Q, is developed on the other arm by an electrical solenoid so that the force generated is proportional to the current, i, passing through the coil. This current is, in turn, provided by an amplifier, the input of which is derived from the displacement detector and is thus a measure of the deviation, x, of the balance arm from the horizontal position. A is the sensitivity factor of the detector and amplifier.

$$\text{Thus : } i = Af(x).$$

The balance arm will be displaced until a condition of equilibrium is achieved, where :

$P = k_1Q$, where k_1 is the ratio of the balance arms ;

but $Q = k_2i$, where k_2 is the constant of proportionality relating force developed by the solenoid with the current through it.

Thus $P = k_1k_2i$

and $P = k_1k_2Af(x)$.

The force P, is thus reproduced in terms of i, and the only constants which enter into the calibration are k_1 and k_2. Obviously k_1 is a true constant, but some precautions have to be taken to ensure that k_2 maintains its value over the range of displacement of the balance arm. This condition can, however, be satisfied by using sufficient detector sensitivity and amplifier gain to make the constant A large, and thus restrict the displacement x to a small value.

A laboratory instrument operating on an electrical-null-balance technique for measurement of small differential pressures was developed by the National Physical Laboratory and demonstrated at the Physical Society Exhibition of Scientific Instruments in 1946.[6] In this instrument a current-carrying coil, moving in a uniform magnetic field, was used to provide the restoring force, and the displacement of the weighbridge arm was detected by a photocell screened from a light source by the interposition of a fine-grating shutter carried on the weighbridge arm. The signal from the photocell was amplified by a thermionic amplifier, the output of which was used to excite the restoring coil.

The instrument to be described makes use of a current-carrying coil moving in a permanent magnetic field to produce the restoring force on the sensitive diaphragm, but since no pivot or levers are introduced into the design, mechanical construction is simplified considerably and the inertia of moving parts is kept at a minimum, thus contributing to the instrument's high speed of response. A differential transformer with a moving core is used as the displacement detector, which element has been developed to give a high sensitivity, thus reducing the associated amplifier to its simplest form.

DESCRIPTION OF THE INSTRUMENT

The instrument consists of two units. A head unit, connected to the pressure sources, the differential of which is to be measured, contains a sensitive diaphragm, restoring coil and permanent magnet, and a detector unit. The second unit consists of the amplifier and the necessary power-supply equipment, which serves to amplify the signal received from the displacement detector in the head unit and convert it to a suitable energy level to excite the restoring coil. Any remote indicating meters required, or the operating coil of an automatic controller, are electrically connected to the amplifier unit.

Figure 2 shows the constructional details of the head unit. A rigid diaphragm, D, on either side of which the differential pressures are applied, is freely mounted and carried on a horizontal-rod axis, which is supported by a flexible four-pillar system, so that the minimum restraint is put on the motion of the diaphragm along its axis, while the necessary rigidity is provided normal to its axis. The coil C, mounted on one end of the diaphragm axis and free to move in the field of a strong permanent magnet, provides the restoring force on the diaphragm. The moving-coil and permanent-magnet arrangement is similar to that used in a normal moving-coil loudspeaker. The detector unit, A, develops a voltage approximately proportional to the movement of the diaphragm from its central position, and this voltage is applied to the amplifier, the output of which supplies the current to the restoring coil.

The principle of operation of the instrument is as follows. On the application of a differential pressure to the diaphragm an axial displacement results, which, by means of the detector element, gives rise to a signal in the amplifier input, thereby causing a restoring force to be developed by the restoring coil. A condition of equilibrium, at which the displacement is just sufficient to provide a balancing force equal to that arising from the differential pressure on the diaphragm, is automatically achieved. At this condition the current in the restoring coil will be a proportionate measure of the differential pressure, provided only that the force developed by this coil is accurately proportional to the current through it, and that the only force opposing motion of the

diaphragm is that developed by the restoring coil. In other words the diaphragm must be mounted as freely as possible.

Provided that these requirements are satisfied the only parameter entering into the calibration of the instrument is the constant which relates the current in the restoring coil to the force developed. By paying careful attention to the design of the permanent magnet (or electromagnet) and the moving coil this parameter can be relied upon to remain constant over long periods of time.

It is impossible to obtain a perfectly freely mounted diaphragm, but more exact examination of the requirements indicates that the condition of freedom need only be satisfied to the extent that the opposing force, arising from mechanical restraint for the displacements to be encountered, is negligible compared with the actuating force developed by the application of the differential pressure to the diaphragm. The required condition can be achieved for a particular range of pressures, either by employing a sufficiently large diaphragm or by increasing the sensitivity of the detector and amplifier, thereby decreasing the displacement of the diaphragm for a particular pressure.

The maintenance of the required proportional relationship between the current in the restoring coil and the force generated is largely governed by the magnitude of the coil displacements, and the smaller these can be made the better. The constant of proportionality can, however, be maintained for quite large displacements by suitable choice of the relative dimensions of the coil and the uniform portion of the magnetic field in which it operates. It must be borne in mind that as the displacements of the diaphragm that can be tolerated, while still satisfying the above conditions, grow larger, the instrument will be less subject to errors arising from distortion of the framework, such as might be caused by non-uniform thermal expansion, or by machining tolerances during manufacture.

With the present design of instrument a diaphragm displacement of about 1 mm. occurs under the application of the maximum differential pressure of 0·1 in. W.G. (35-g. force on the diaphragm), and the freedom of the diaphragm is such that the mechanical restraint introduced for a displacement of 1 mm. is not more than about 0·4 g. Taking into account this mechanical restraint and the small reaction force developed by the detector (which is discussed later), the total restraining force on the diaphragm from these sources is less than 1/30th part of the restraint produced by the moving coil. The effective percentage of feed-back in the measuring system is thus of the order of 97%. This results in a high stability of calibration of the instrument, and makes it independent of normal variations in amplifier gain, or variations in the spring strength of the diaphragm mounting or suspension system. It is also clear that with this order of percentage feed-back no appreciable drift in the zero reading of the instrument can be expected with normal distortions of the frame such as might tend to move the detector assembly relative to the diaphragm system. The stability of calibration which is possible with this arrangement and its freedom from zero drift, are considered of first importance in simplifying the mechanical design of the instrument and reducing the dependence of its performance on the conditions under which it is operated.

An experimental model of the instrument was the subject of a paper presented to the Society of Instrument Technology[7, 8] in March 1948, and was demonstrated at the Physical Society Exhibition of 1948.

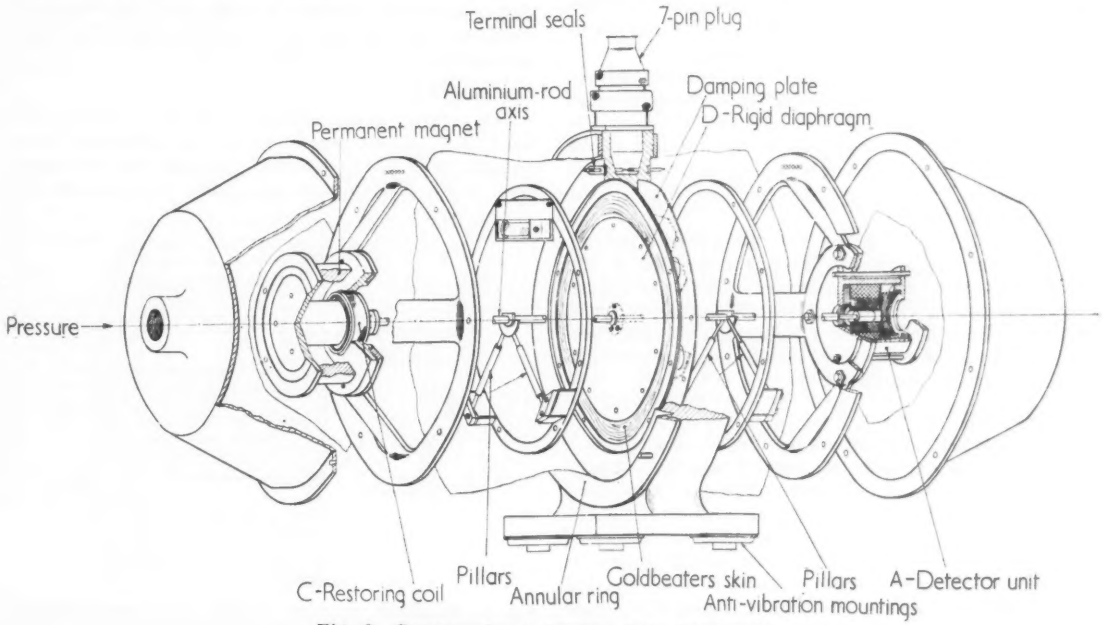


Fig. 2—Constructional details of the head unit

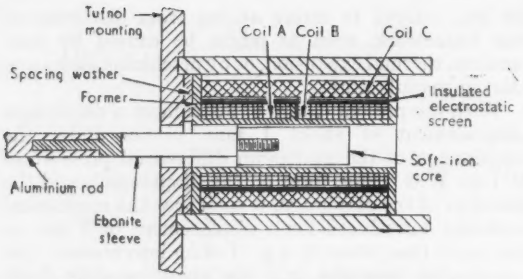


Fig. 3—Sectional view of the detector unit

In the light of experience gained with this experimental equipment, both in the laboratory and in a melting shop, an improved instrument has been designed and a prototype model built. The constructional details of this instrument and the associated amplifier are discussed in the following paragraphs.

The Diaphragm, Mounting, and Supports

The diaphragm, mounting, and supports can be seen in Fig. 2. The diaphragm consists of a thin, rigid, 5-in. dia. disc of paxolin, its centre boss being carried on a horizontal aluminium-rod axis. This diaphragm is mounted inside the annular ring forming the frame of the measuring head, the intervening space being sealed off by an annulus of gold-beater's skin which forms the seal between the two sides of the diaphragm to which the differential pressures are applied.

The aluminium-rod axis carrying the diaphragm is supported by four pillars, each of which consists of a length of aluminium rod connected at its ends by short lengths of beryllium-copper strip. These pillars are very rigid along their length and accurately position the centre axis of the diaphragm, but they provide a high degree of flexibility to bending, which allows free axial motion of the diaphragm.

A damping plate, consisting of a circular disc of brass with a central hole through which the diaphragm axis can pass, is fitted on one side of the diaphragm so as to provide air damping on the motion of the diaphragm. The degree of damping can be adjusted by removing screw caps covering openings in the damping disc.

In the construction of the diaphragm and its support care is taken to keep the inertia of the moving parts as low as possible, in order to reduce the tendency of the system to self-oscillation when high amplifier and detector sensitivity is used, and thus minimize the degree of air damping required to maintain stable operation.

The Detector Unit

The detector unit, shown in Fig. 3, consists of a three-winding solenoid, the core of which is formed by a short length of soft-iron rod of $\frac{1}{4}$ in. dia. fixed to the end of the aluminium-rod axis carrying the diaphragm. The core is less than half the length of the solenoid. Winding *C*, shown in the figure, is placed centrally over windings *A* and *B*, and is excited from a 50-cycle source. Windings *A* and *B* are connected in opposition, and thus show zero induced voltage when the soft iron core is symmetrically located within them. Displacement of the core to the right or left results in a voltage being induced in *A* and *B* of an amplitude approximately proportional to the displacement, and of a phase dependent on the direction of the displacement. An output voltage of approximately 0·75 V. is obtained for a 1-mm. displacement of the core from its central position. The reaction force on the core of the detector, when displaced from its central position, is approximately 0·3 g. for 1 mm. displacement with the normal loading on the detector output.

The Restoring-Force Coil and Permanent Magnet

The moving-coil and permanent-magnet system used is similar to that found in the normal moving-coil loudspeaker (*see* Fig. 4). The pot-type magnet is constructed from an annular-ring Ticonal magnet, the remainder of the magnetic circuit and pole system being made from annealed mild steel. The dimensions of the magnet and air gap are such that a gap flux density of approximately 2000 gauss is produced.

The restoring coil consists of 600 turns of 39 S.W.G. enamelled wire wound on a Tufnol former. The length of the coil is about 1·4 times the length of the air gap, which permits an axial movement of the coil in the gap relative to its central position of about $\pm$ 2 mm., without appreciable change in the constant that relates force on the coil to current through it.

The flux density in the air gap and the number of turns on the coil are so designed that a force of approximately 35 g. (corresponding to a differential pressure of 0·1 in. W.G. on an effective diaphragm diameter of 5·3 in.) is developed for a coil current of 30 m.amp. The calibration of the instrument is finally adjusted by a shunt resistance across the coil, in order to obtain an exact calibration of 30 m.amp. for a 0·1-in. W.G. differential pressure. This calibration constant is chosen to suit available current recorders and the automatic control equipment with which the instrument is to be used.

The Amplifier

The purpose of the amplifier unit is to convert the small A.C. signal developed in the detector to a suitable level of D.C. current to energize the restoring-force coil. Working on the basis of a maximum

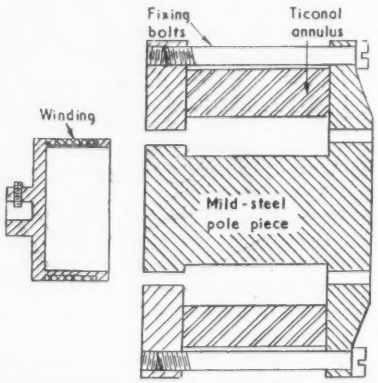


Fig. 4—Sectional view of magnet and restoring-coil system

diaphragm displacement of 1 mm., which gives rise to an output of 0·75 V. from the detector, it is clear that the amplifier gain must be such as to give a D.C. output of approx. 30 m.amp. for this value of signal. Furthermore, the rectification must take account of the phase of the signal developed by the detector, since this determines the direction of the displacement of the diaphragm. This also must govern the polarity of the current in the restoring coil so that the balancing force is generated in the appropriate direction.

Referring to the circuit diagram (Fig. 5) the detector voltage is applied through step-up transformer T_2 to the grids of the power pentodes V_1 and V_2, the anodes of which are fed in anti-phase with 400 V. from the main transformer. Condenser C_4 is introduced to adjust the phase of the grid voltages so that they are in phase or in anti-phase with the anode voltages. An analysis of this circuit will show that the pentodes act as grid-controlled full-wave rectifiers, the total anode current which is passed through the restoring coil being dependent on the amplitude of the grid voltages. With an input voltage of one phase the valves conduct heavily, and as this voltage is reduced to zero and then increased in the opposite phase the total anode current falls to zero.

In order that the valves can be operated on the optimum portion of their characteristic, while still giving a range of control of the current in the restoring coil from 0 to 30 m.amp., a backing-off current is passed through the coil. This current is supplied from an A.C. source through rectifier W_3, and control resistance R_7.

The indicating meters, recorders, or operating coil of an automatic controller are connected in series with the restoring coil. The circuit is designed to allow for an automatic-controller operating coil resistance of 3000 ohms, and if this is not in use a resistance R' is included to maintain the total series resistance at the value for which the circuit is designed.

Although the instrument is normally required for use on a pressure range of from 0 to 0·1 in. W.G., and the operating range of the current in the restoring coil is 0 to 30 m.amp., it is clear that by adjustment of the backing-off current referred to earlier the range can be extended to operate from, say, − 0·02 in. W.G. to + 0·1 in. W.G., the reverse currents in the coil being provided by the backing-off current.

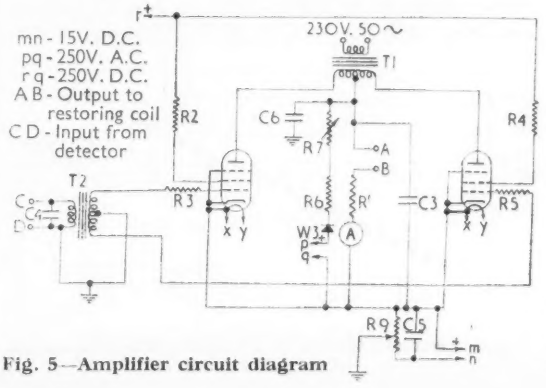


Fig. 5—Amplifier circuit diagram

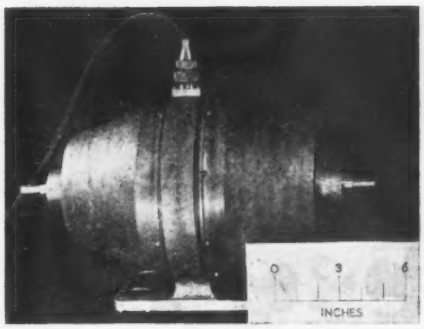


Fig. 6—The head unit as finally assembled

In the design of the amplifier and rectifier circuit consideration has been given to simplicity and reliability of operation. Even in the case of complete failure of one valve the circuit continues to operate, but with reduced efficiency, the only difference being that the effective output current for a given input voltage is halved, and half-wave rectification occurs instead of full-wave. This only seriously affects the calibration of the instrument in the higher portion of the pressure range (0·05 in. W.G. upwards) as will be shown later.

GENERAL ARRANGEMENT OF THE INSTRUMENT AND METHOD OF INSTALLATION ON A FURNACE

The constructional details of the head unit are shown in Fig. 2, and Fig. 6 shows the unit as finally assembled. Figure 7 shows the construction of the amplifier unit which is linked to the head unit by a five-core cable, and to the required indicating meters, or recorders, by a two-core cable. The performance of the equipment is not affected by the lengths of these interconnecting cables, nor is any special quality or screened cable required.

The first model of the instrument described has been installed on an open-hearth furnace at Messrs. Samuel Fox and Co., Ltd., Stocksbridge Works. Figure 8 shows the position of the head unit relative to the furnace in this installation.

PERFORMANCE OF THE INSTRUMENT

Figure 9 shows a current/differential-pressure calibration curve for the instrument, the results of an experiment carried out in the laboratory, using a precision water manometer for the reference pressure measurement. The scatter of the points on this curve is not more than the precision with which measurements could be made with the manometer. This calibration curve was accurately reproduced in calibrations carried out over a period of three weeks, including a period of operation on the furnace, after which the head unit was dismantled and reassembled, no change in calibration being detected.

The other curve in Fig. 9 shows a calibration of the instrument carried out with only one amplifier valve in position. It shows that reasonable performance is still obtained over half of the operating range. Further calibrations were carried out in which the excitation voltage supplied to the detector coil was

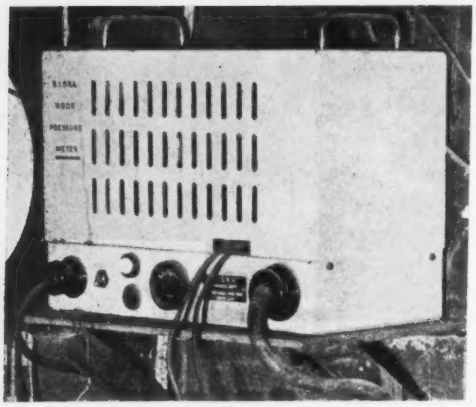


Fig. 7—The amplifier in position

varied by as much as 50%, which is equivalent to a change of gain of the amplifier of 50%, and still no change in calibration of the instrument could be detected. These points are included in Fig. 9.

As mentioned earlier, a first model of this instrument has been installed in a melting shop, and has now been operating satisfactorily for six months in the position indicated in Fig. 8.

CONCLUSIONS

Although the design of the instrument described in this paper adopts a relatively new technique for measurement of small differential pressures under industrial conditions, it is thought that it can, when finally engineered, be applied with considerable advantage, both in research and in industry, for measurement of low differential pressures. The following advantages are claimed :

1. The design of the instrument permits a high degree of stability of calibration and freedom from zero drift in the measurement of low differential pressures, while still maintaining a simple mechanical construction in which reasonably large machining tolerances can be allowed without detrimental effect to the instrument performance. This stability of calibration also means that less precautions need be taken to protect the instrument from temperature fluctuations, vibration, and other disturbances encountered in industrial applications.

2. The method of measurement could be readily applied to measurement of gas and air flow in furnace systems where orifice plate or Venturi techniques are used, and where it is desirable to use as small a differential pressure as possible across the orifice, in order to reduce the loss of pressure in the gas or air supply system.

3. The principle of operation permits remote indication and recording of the instrument readings in terms of an electrical signal, without the restriction of distance, or without requiring the use of long runs of pressure piping.

4. The instrument has a high speed of response to pressure fluctuations, and is therefore suitable for use with automatic-control equipment. Since the measuring head can be connected close to the pressure measuring point, and the controller or recorder installed at any desired distance from the measuring head, any deterioration in response speed, such as is incurred by long runs of pressure piping, is avoided.

5. The thermionic amplifier and rectifier unit is of a very simple form and lends itself to robust construction suitable for works use. In any properly designed electronic amplifier, the element which tends to reduce the reliability of operation is the thermionic valve, because of its indeterminate life and the variability of its parameters with operating voltages and age. However, because of the high percentage of feed-back used in this instrument, the variability of the valve parameters does not influence the instrument calibration, and the indeterminate valve life is effectively taken care of, because the instrument will continue to operate in spite of a valve failure. Failure of one valve during operation can be readily shown by an indicator lamp on the amplifier unit, and valve replacement is one of the simplest and quickest maintenance tasks.

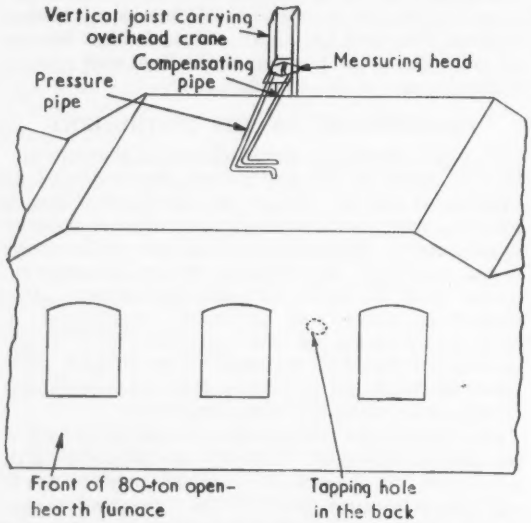


Fig. 8—Position of the measuring head relative to the furnace

Acknowledgments

The authors are indebted to their Director, Sir Charles Goodeve, and to Mr. Thring, Head of the Physics Department, for their advice, encouragement, and keen interest shown in the carrying out of this

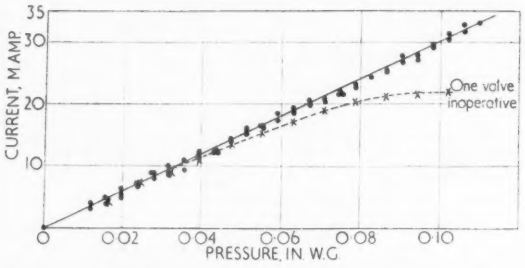


Fig. 9—Current/differential pressure calibration curves of the instrument

work, also to the management and staff of Messrs. Samuel Fox and Co., Ltd., and The United Steel Companies' Central Research and Development Department for their co-operation in carrying out works trials. Their thanks go to their colleagues in the Physics Department, for assistance on various problems arising in the course of the work, to the Research Department of Messrs. William Jessop and Sons, and to the Magnet Department of Mullard Electronic Products, Ltd. for assistance in the design of the permanent magnet used in the instrument.

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6. " An Electrical Micro-manometer." Catalogue of the Physical Society Exhibition of Scientific Instruments, 1946, p. 246.
7. S. S. CARLISLE and B. O. SMITH : " An Experimental Pressure Meter." Paper presented to the Society of Instrument Technology, 30th March, 1948.
8. Provisional Patent Application No. 8244/48.

CORRIGENDUM

Thermodynamics of Substances of Interest in Iron and Steel Making

The authors wish to correct the following errors and inaccuracies in the paper on " *The Thermodynamics of Substances of Interest in Iron and Steel Making from 0° C. to 2400° C. I—Oxides*," by F. D. Richardson and J. H. E. Jeffes (*Journal of The Iron and Steel Institute*, 1948, vol. 160, Nov., pp. 261–270) :

Page 263

Fig. 1 : The line for $6FeO + O_2 \rightarrow 2Fe_3O_4$ should end at 1369° C. Symbols should be inserted for the melting point of cobalt at 1490° C., and of silicon at 1427° C., and for the transition point of silica at 1470° C. The line for $Si + O_2 \rightarrow SiO_2$ is incorrect between 1427° and 1700° C. ; it should break at 1427° C. (not at 1470° C., as in the figure) and should then run directly to the melting point of silica at 1700° C.

Page 264

Left-Hand Column

Line 10 from bottom of page : Equation (4) should read :

$$K_T = \text{antilog}_{10} \frac{-\Delta G^\circ_T}{4{\cdot}57T}$$

Line 8 from bottom of page : m_1X_z should read m_1M_z.

Line 5 from bottom of page : Equation (5) should read :

$$K_T = \frac{(M_xO_y)^{m_z}}{(X_z)^{m_1} p_{O_2}} = \frac{1}{p_{O_2}}$$

Right-Hand Column

Line 16 from bottom of page : 1470° C. should read 1660° C.

Line 13 from bottom of page : $10^3/1$ should read $5{\cdot}6 \times 10^3/1$.

Line 12 from bottom of page : " Reduction of Oxides by Carbon"—Owing to a tracing error which does not affect either the diagram or the Appendix, the examples worked in this section for MnO are not precisely in agreement with Fig. 1, although they are within the error limits.

Page 265

Left-Hand Column

Line 20 from top of page : Equation (15) should read :

$2MnO + C \rightarrow 2Mn + CO_2$ $\Delta G^\circ_{1410^\circ C.} = +28{\cdot}0$ kg.cal.

Line 29 from bottom of page should read :

$$p_{CO_2} = \text{antilog} \frac{-28{,}000}{4{\cdot}57 \times 1683}$$

Line 16 from bottom : -160 should read -106.

Line 8 from bottom : $1{\cdot}44 \times 10^{-6}$ should read $\sqrt{1{\cdot}44 \times 10^{-6}}$.

Right-Hand Column

Line 18 from top of page : " equation (8) " should read " equation (12) "

Page 267

Left-Hand Column

Lines 5 and 4 from bottom of page : The equations for cobalt should read :

$$\Delta G^\circ_{298-1763^\circ K.} = -111{,}800 + 34{\cdot}75T$$
$$\Delta G^\circ_{1763-2093^\circ K.} = -119{,}700 + 39{\cdot}20T$$

Right-Hand Column

Line 14 from bottom of page : The equation should read :

$$\Delta G^\circ_{298-1730^\circ K.} = -119{,}250 + 67{\cdot}25T$$

Note—The method of calculating this curve was misquoted in the original paper. The procedure adopted was to draw the best line through the experimental results of Walden (*Journal of the American Chemical Society*, 1908, vol. 30, p. 1350), Simon and Schmidt (reference 53 of the paper), and Ruer and Nakamoto (reference 47), who measured the equilibrium oxygen pressures exerted by Fe_2O_3 in the presence of Fe_3O_4. The line at the low-temperature end does not agree well with the value of $\Delta G^\circ_{25^\circ C.}$ calculated from the value of $\Delta H^\circ_{25^\circ C.}$, derived from the heats of formation of Fe_2O_3 and Fe_3O_4 cited by Bichowsky and Rossini (reference 3), and the necessary entropies at 25° C. from Kelley (reference 34). It is, however, within the possible limits of error. The more recent measurements of the equilibrium at high temperature by Darken and Gurry (*Journal of the American Chemical Society*, 1946, vol. 68, p. 798) were overlooked when the curve was calculated, but these results have since been found to be in complete agreement with the high-temperature end. Here the accuracy may safely be considered as *B*. Owing to the non-stoichiometry of magnetite in equilibrium with hematite, the equation given is strictly stoichiometric with respect to oxygen only.

Iron ($\frac{3}{2}Fe + O_2 \rightarrow \frac{1}{2}Fe_3O_4$). Accuracy *B*

$$\Delta G^\circ_{298-833^\circ K.} = -133{,}900 + 41{\cdot}1T$$

This curve, which was not shown on the diagram, was calculated directly from the measurements by Emmett and Schultz (*Journal of the American Chemical Society*, 1933, vol. 55, p. 1376) of the equilibrium between iron, magnetite, hydrogen, and water vapour. Since this curve can also be derived from the appropriate FeO and Fe_3O_4 curves, provided that allowance is made for non-stoichiometry, it is possible to use Emmett and Schultz's results as a check on the accuracy of these FeO and Fe_3O_4 lines at low temperature. Agreement between the direct and the derived curves is close at 560° C. ; at 0° C. the difference is 3·2 kg. cal.

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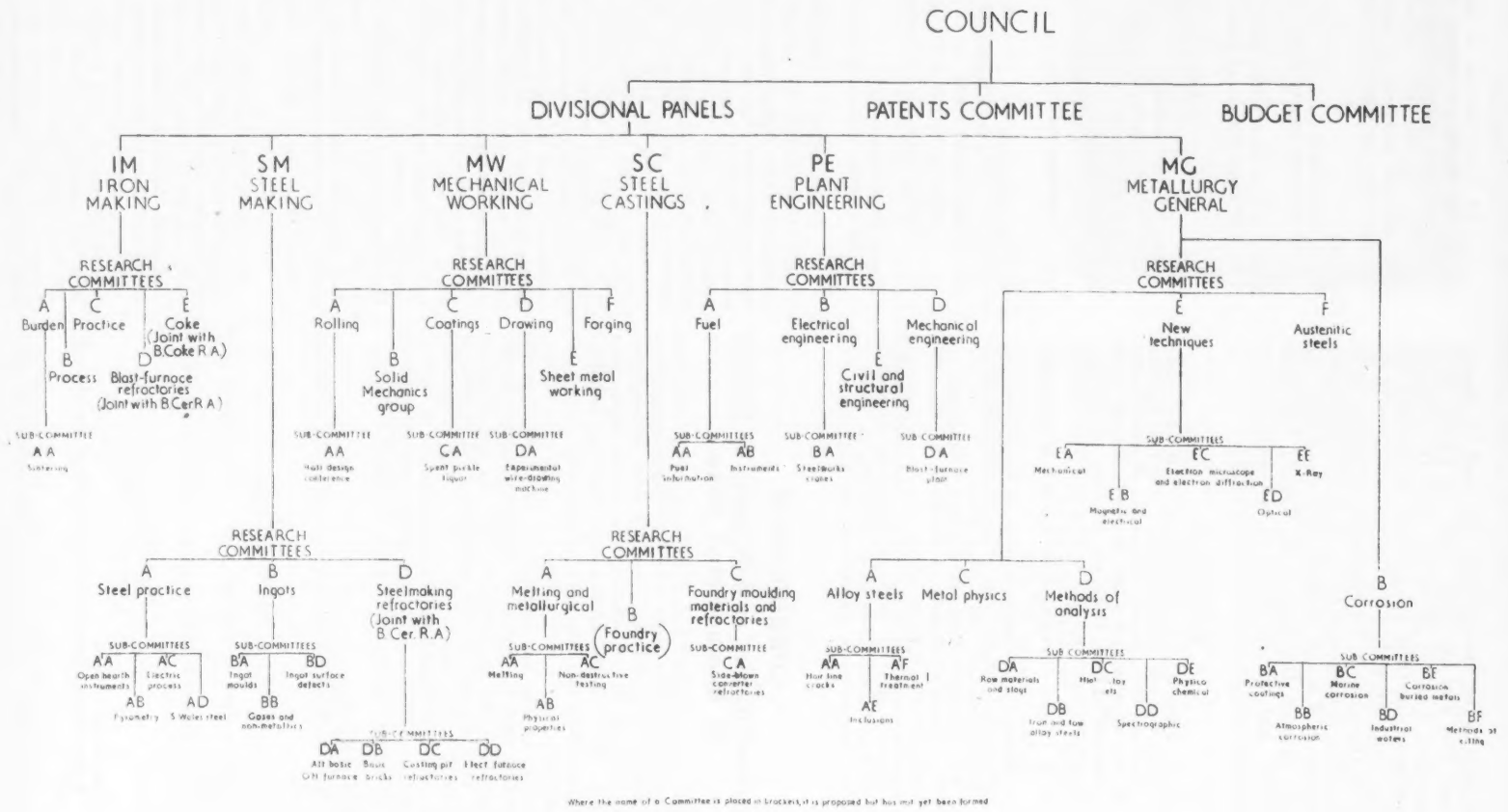

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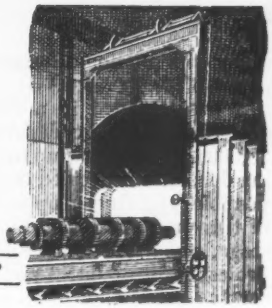


A Review of the Application and Design of Heavy Forging Presses

By J. A. Sanderson, M.I.Mech.E., and J. G. Frith, A.M.I.Mech.E.

SYNOPSIS

The paper describes present-day forging practice, with the tendency towards larger ingot sizes, and the probable press powers which will be required to deal with these ingots.

Details of the size and location of existing heavy presses are given, together with lists of the ingot capacities of the various sizes both for forging and upsetting, and British and American practice in these respects are compared.

Various methods of press construction, particularly as regards the guiding of the crosshead, are considered, and the influence of these methods upon the number of main cylinders and upon the choice of press drive is discussed.

The steam-hydraulic, direct pump, and pump and air-hydraulic accumulator types of press drive are described, with particulars of the sizes of pumps used, and a 12,000-ton press supplied to the U.S.S.R. in 1939 is selected for the consideration of detailed features of design.

PRESENT-DAY FORGING PRACTICE

During recent years there has been a growing demand for certain heavy forgings for industrial requirements, such as high-pressure boiler drums, chemical vessels, turbine rotors, rolls, etc., not only of increased dimensions but of a higher quality. The heavier ingots required are beyond the capacity of the older forges, which, although they are actually handling these heavier ingots, require much attention and expense to be kept at work.

To achieve the most economical capital and running costs, forgemasters in the past based the power of the press, not on the maximum, but on the average, ingot size to be worked, and what the press lacked in power was made up by more heats and longer times for the heaviest forgings. This view is not now shared by well-informed forge executives, and it is generally recognized that, in order to keep abreast of rapid technical developments, such as the process of upsetting the ingot, new forge equipment and more powerful presses, up to 15,000 tons' power, must be installed.

Future Power Requirements

The question naturally arises whether 15,000 tons represents finality as regards power, or if there is a possibility of a further increase. The following particulars of how the first forging press of 15,000 tons' power came to be adopted and how a much more powerful one of 40,000 tons' power came to be projected and the construction actually commenced, will throw some light on this aspect and show how, for the present, the limiting factor is the weight up to which the heaviest ingot can be cast.

Krupps were the first to adopt a forging press of 15,000 tons' power. Previously, they were limited to two of 4000–5000 tons, supplied in 1908. It is interesting to record that in a discussion with one of the authors, in about 1929, a Krupp's forge engineer stated that he favoured a power of 10,000 tons, but shortly afterwards it was announced that Krupps had built one of 15,000 tons.

An explanation of this, given only recently by one of Krupp's directors, was that 10,000 tons was sufficient, but the engineering department thought it was only a question of time before it would be necessary to deal with heavier ingots, and it was decided to increase the power to 15,000 tons. To obtain this, they employed a single steam hydraulic intensifier, following the type and controlling gear of the 4000-ton press supplied in 1908, described later as one of 5000 tons, after increasing the working pressure.

After the second world war the forging world was startled with the announcement that Krupps had

Manuscript received 7th January, 1949.

Mr. Sanderson and Mr. Frith are at the Davy and United Engineering Co., Ltd.

under construction a forging press of the stupendous power of 40,000 tons.[1] It was found that the power had been decided in a similar manner to its predecessor; the forge department wanted a press of 30,000 tons for ingots up to 400 tons, but the engineering department decided on 40,000 tons to provide for possible future ingots up to 500 tons. The construction of this press, however, was little beyond the design stage, when the termination of the war stopped the project; it is doubtful whether there will be any call for the production of such a powerful press in the future in view of the changes which may be brought about by the use of atomic energy.

Maximum Ingot Weight

In 1930 Krupps regarded an ingot of 130 tons as the limit of their achievement, but in 1931 they successfully made ingots of 230 tons, octagonal in shape, 98 in. in dia. and 296 in. long. In 1933 it was announced that the English Steel Corporation, Ltd., of Sheffield, were re-equipping their forge with a 7000-ton forging press to deal with ingots up to 250 tons. Apparently about that time Krupps were not thinking of ingots of more than 300 tons. Information obtained in 1946 was that they had already forged ingots up to 280 tons, and they claimed that the quality of the forging obtained with such a powerful press was greatly in advance of anything that could be obtained from a smaller press.

Only the future can tell if ingots of over 300 tons will ever be required and if they can successfully be made. Ingots of 250 tons or more are made only with difficulty, and with considerable risk, since, being in excess of the capacity of a single open-hearth furnace suitable for such steel, they must be run from a group of furnaces. Preparing the steel ready for teeming practically at the same time from at least four furnaces, the handling for continuity of teeming, and the length of casting time, all present their difficulties.

The first job of the 15,000-ton press was to forge for itself a new set of press columns, owing to the impossibility, it was said, of making satisfactory forgings from the smaller press of 5000 tons. The dimensions of these columns are 33 in. in dia., with a finished weight of about 86 tons, and they require an ingot of some 150 tons' cast weight. The shop for the 15,000-ton press was equipped with two cranes of not more than 300 tons' capacity which, in itself, seems to indicate that ingots of 300 tons—if achieved—would be exceptional and the absolute limit at that time. Visits to Germany since the war have revealed that the proposed 40,000-ton press was intended to deal with 400-ton ingots as a regular production and that the shop was to be equipped with 400-ton cranes, in the hope that with two of these in operation together, ingots up to 600 tons could be handled.

THE WORLD'S PRINCIPAL HEAVY FORGING PRESSES

It is of vital interest, in considering any increase in heavy-forge capacity or replacement of obsolescent plant, to review the world's heavy forge plant and to know how the forge equipment of one country compares with that of another.

Details of the world's principal forging presses of 5000 tons and over, are given in Table I, and are exclusive of those for special work, such as armour bending, railway wheels and tyres, and non-ferrous work. The 18,000-ton press at the Wyman-Gordon plant, Worcester, Mass., which is said to be the largest press in America, is not included as it is essentially a die-forging press.

According to recent information, the 15,000-ton forging presses at Krupps and Dortmund are due for demolition. From Table I, it will be seen that this leaves Russia as the possessor of the most powerful forging presses in Europe, *viz.*, one of 15,000 tons, two of 10,000 tons, and one (acquired in 1939) of 12,000 tons, to deal with ingots up to 250 tons. The presses in France, Great Britain, and the other countries all have powers of 5000 to 7000 tons, with the exception of the 8000–12,000-ton combination forging and bending press at Terni, in Italy.

Outside Europe, Japan has one press of 15,000 tons, and another of 12,000 tons which was in course of construction and delivered in part during the recent war. In the early years of this century, the U.S.A. had no less than three forging presses having powers of 10,000 tons or over, all of which are still in use, although the Midvale 10,000-ton press has now been reduced to 7500 tons, by a decrease in the working pressure, and the 14,000-ton press at Bethlehem is used solely for armour-plate work. In more recent times, four 14,000-ton presses and five 6000 and 7500-ton presses have been built, and although in each case these were put down primarily to meet war requirements, it does seem that a pattern has been established of two main groups, corresponding to equivalent British sizes of 12,000 and 6000 tons.

THE HEAVY FORGING INDUSTRY IN GREAT BRITAIN

As already indicated, Great Britain has no large forging presses of the order of 12,000–15,000 tons' power, the largest at present in operation being one of 7000 tons and two of 6000 tons. The installation of a new heavy forge with a forging press of 12,000–15,000 tons, and all that it entails, is a project of very considerable magnitude, and in view of the expenditure involved, responsible authorities will be concerned whether such a powerful press is likely to be kept sufficiently employed to make it a satisfactory economic proposition. However, the quality demanded today for forgings can only be achieved by the modern method of upsetting during forging, and this cannot be done with less than the powers mentioned. A press of 12,000 or 15,000 tons, is virtually an upsetting press. Krupp's practice in the production of important forgings such as rotors, crankshafts, etc., was to employ a 15,000-ton press for upsetting, and a 5000-ton press for forging.

The capital and running costs of a 15,000-ton press are proportionately greater than for one of 12,000 tons, so the immediate question in considering a new project is whether a 12,000-ton press is adequate to meet the needs of the future. If it is accepted that heavy armament is to be displaced by aerial weapons, and that the heaviest forgings required will be those for industrial purposes, then there are reasonable

Table I

REVIEW OF THE WORLD'S HEAVY STEEL FORGING PRESSES (5000 TONS AND OVER)

Name of Firm	Capacity of Press, tons	Maker	Year	Remarks
Great Britain				
English Steel Corporation, Ltd., Sheffield	7000	Armstrong-Whitworth	1913	Originally steam-pump driven, converted to electric direct pump drive, 1934
Thos. Firth and John Brown, Ltd., Sheffield	6000	Davy Brothers	1911	Duplex type, steam intensifier
Wm. Beardmore and Co., Ltd., Glasgow	6000	Duncan Stewart, now part of Davy and United Engineering Co., Ltd.	1934	Duplex type, steam intensifier
France				
Marrel Frères, Rive-de-Gier	6000	Breuer Schumacher	1906	Originally steam intensifier, converted to electric-rack-driven intensifier by Sack, 1936
Chatillon-Commentry, Montlucon	6000	Haniel and Lueg	1921	3-stage, pump and air-loaded accumulator
Aciéries de la Marine, St. Chamond	6000			Steam intensifier, very old press
Aciéries de Firminy, Firminy	6000	Horme and Buire	1914	Steam intensifier
Germany				
Krupp A.G., Essen	5000	Davy Brothers	1908	Duplex type, steam intensifier
" " "	15,000	Krupp	1928	3-cyl., steam intensifier
" " "	5000	Krupp	1941	Duplex type, steam intensifier, copy of 1908 press, but built by themselves
Dortmund-Hörde, Dortmund	15,000	Kreuser-Wagner	1932	2-cyl., pump and air-loaded accumulator
Gutehoffnungshütte, Düsseldorf	5100	Schloemann		3-cyl., pump and air-loaded accumulator
Stalwerk Braunschweig Werk	5100	Schloemann		" " " " "
Ruhrstahl A.G., Hattingen	6000	Hidraulic-Duisburg G.m.b.H.		" " " " "
Czechoslovakia				
Witkowitz Bergbau und Eisenhütten Gewerkschaft, Witkowitz	4500	Davy Brothers	1908	Duplex, steam intensifier
" " " "	6000	" "	1933	" " "
Skodawerk	5000	" "		
Italy				
" Terni " Soc. per L'Industria e L'Elettricita, Terni	4500	Davy Brothers	1910	Duplex, water turbine and flywheel. Direct pump drive
" " " "	8000–12,000	" "	1934	3-cyl. combination 8000 tons forging, 12,000 tons armour-bending press. Electric Ilgner direct pump drive
Russia				
Barracada Works, Stalingrad	6000	Davy Brothers	1914	Parts lost at sea during 1914–18 war, completed 1932. Duplex, steam intensifier
Kramatorsky Machine Building Works, Kramatorsky	15,000	Schloemann	1935	3-cyl. with central guide stalk, steam intensifier
Uralmash Maching Building Works, Urals	(Two) 10,000	Hidraulic-Duisburg G.m.b.H.	1934	3-cyl., steam-hydraulic intensifier
" " " "	6000	" " "	1934	3-cyl., steam intensifier
Putiloff Works, Leningrad (probably)	12,000	Davy and United Engineering Co., Ltd.	1939	Duplex, steam hydraulic, 4 intensifiers, for conversion later to electric Ilgner direct pump drive
Japan				
Japanese Government	6000	Davy Brothers	1916	Duplex, steam intensifier
" "	15,000	Hidraulic-Duisburg G.m.b.H.	1935	3-cyl., pump and air-loaded accumulator
" "	12,000	United Engineering and Foundry Co., Pittsburgh	1938	3-cyl., pump and air-loaded accumulator. Parts delivered during early part of War
United States of America				
Bethlehem Steel	14,000	Bethlehem	1893	2 main cyl., no guide stalk, steam-driven pumps
Carnegie-Illinois, Homestead	12,000	Believed to be Bethlehem	1900 or earlier	2 main cyl., no guide stalk, steam-driven pumps
Midvale Steel	7500 originally built as 10,000 tons)	Midvale	1904	1 main cyl., steam-driven pumps, ram rigidly attached to crosshead
U.S. Navy, S. Charleston	14,000	Mesta Machine Co.	1919	3 main cyl., oblique struts from base to entablature, steam-intensifier drive
Midvale Steel	6500	United Engineering and Foundry Co., Pittsburgh	1920	2 main cyl., central guide stalk, steam-pump drive
Bethlehem Steel	7500	Mesta Machine Co.	1940	2 main cyl., no guide stalk, steam-intensifier drive
U.S. Navy, S. Charleston	6500	United Engineering and Foundry Co., Pittsburgh	1944	2 main cyl., central guide stalk, reciprocating pumps and air-loaded accumulator
" " " "	14,000	Mesta Machine Co.	1944	3 main cyl., oblique struts, from base to entablature, centrifugal pumps with air-loaded accumulator
Carnegie-Illinois, Homestead	7000	" " "	1944	2 main cyl., no central guide stalk, centrifugal pumps with air-loaded accumulator
U.S. Navy, S. Charleston	14,000	United Engineering and Foundry Co., Pittsburgh	1944	2 main cyl., new type guide stalk, reciprocating pumps with air-loaded accumulator
Midvale Steel	14,000	" " " "	1945	2 main cyl., new type guide stalk, steam intensifier drive (2 intensifiers)
Mesta Machine Co.	6000	Mesta Machine Co.	1945	2 main cyl., no guide stalk, centrifugal pumps with air-loaded accumulator

grounds for the belief that present and future requirements will be within the capacity of a 12,000-ton press for ingots up to 250 tons. To assist in deciding such an important question, the authors have prepared the following data giving (1) the capacity of forging presses in terms of ingot capacity for ordinary forging, and (2) their range of capacity for upsetting before and during forging :

(1) *Ingot Capacity of Forging Presses for Normal Forging (British Practice)*

Power of Press, tons	Ingot Size Across Flats, in.	Approx. Gross Wt. of Ingot, tons
3000	60	60
4000	72	80
5000	84	100
6000	90	120
8000	96	160
10,000	100	200
12,000	110	250
15,000	112	300

(2) *Upsetting Capacity of Forging Presses (British Practice)*

Power of Press, tons	Size of Ingot Across Flats, or Dia. after Forging and Removal of Discard, in.	Approx. Wt. with Discard Removed, tons
3000	30–43	15–30
4000	34–48	20–40
5000	38–53	25–50
6000	42–60	30–60
8000	48–69	45–90
10,000	55–77	60–120
12,000	60–84	75–150
15,000	70–98	100–200

The sizes of ingots given do not represent the absolute limit, but the maximum that can be forged effectively, as the use of narrower tools and more heats provides a degree of elasticity by which the capacity can be increased by nearly 50%, but with diminution in the quality of the product.

In upsetting, the tools must be large enough to cover the diameter at the termination of the squeeze, and the increase in diameter will naturally depend on the amount of reduction (which may be from 30 to 66%) of the original height of the ingot.

The power required is also dependent, although to a lesser degree, on other conditions, such as the uniformity of the heating of the ingot, forging temperature, and the composition of the steel, so it is possible to give the range of upsetting capacity for each power of press only in very general terms.

A COMPARISON OF BRITISH AND AMERICAN PRACTICE

The figures given in Table II are based on the practice of several leading American companies, and may be taken as representative of normal procedure, although in each case larger or heavier ingots could be worked with the power available if more heats or narrower tools were adopted. Figures for representative British practice are also given for comparison. The smallest of these three ranges of press power clearly shows the difference between practice in the two countries, although in fairness it must be stated that other American presses of around this power are largely engaged upon smaller ingots of, say, 30 tons.

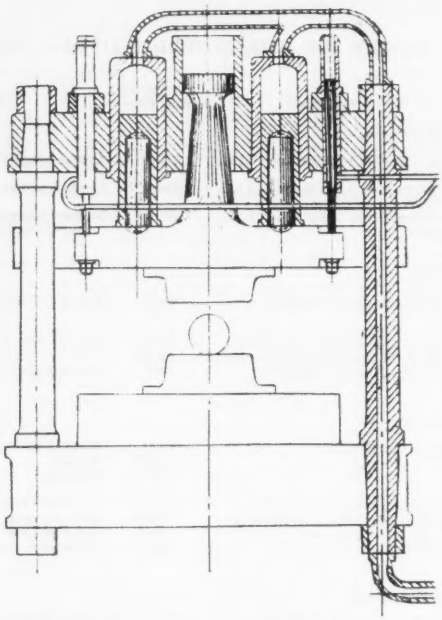


Fig. 1—Sectional view of cylinders of 4000-ton Duplex forging press

As regards upsetting, a leading American authority has stated that, in his opinion, the *maximum* size of ingot which can be upset under a 6000-ton press is an 82-in. octagonal ingot, approximately 160 in. long, with a reduction of 30% in length ; the total weight of this ingot would be approximately 110 tons, both press power and weight being given in long tons. Comparative figures for British practice are 60 in. across flats and 60 tons' weight, after removal of the discard. It should be pointed out, however, that the British figures are intended to indicate normal practice whereas the American figures are absolute maxima. The same authority also considers that a press power of 12,500 long tons will easily upset any ingot which can at present be successfully melted, and quotes instances where a 108-in. octagonal ingot,

Table II

COMPARISON OF BRITISH AND AMERICAN FORGING CAPACITIES

	British			American		
	(1)	(2)	(3)	(1)	(2)	(3)
Press power, long tons	3000	6000	12,000	2700	5800–6700	12,500
Ingot size across flats, in.	60	90	110	77	82	108
Approx. gross wt. of ingot, long tons	60	120	250	80	112	255

approximately 160 in. long on the body, and having a total weight of 245 long tons, has been upset by such a press to a length of 120 in., and in the same heat has had a hole pierced through it for further forging into a hollow vessel. The weight of this ingot, after removal of the discard, would be approximately 180 tons, and although it could be upset successfully in one heat on a press of much less power, the time taken would be considerably more, as the speed at which the upsetting is to be carried out is one of the principal factors which determine the press power required.

THE DESIGN AND CONSTRUCTION OF HEAVY FORGING PRESSES—GENERAL CONSIDERATIONS

Design

Germany has been particularly active in forging-press construction, in respect of both increase in power and the number of presses constructed, but no evidence can be discovered of any marked improvement either in principle or in design.

British observers in Germany have reported that one of the leading authorities on forging-press construction expressed the view that there was very little to choose in actual press design between the leading makers in all countries. As might be expected, some German industrialists still favoured the steam intensifier because of its greater simplicity and elasticity of operation, and although the general consensus of opinion seemed to be in favour of electric power, the leading constructors were divided whether or not to employ hydraulic intensification in conjunction with electric pumps and air-loaded accumulators.

Although different designs of forging press may appear to be of equal merit when judged from examination of drawings alone, only after years of actual working can it be determined which design or construction will prove to be the most satisfactory, as it is only then that fundamental weaknesses begin to show themselves and become troublesome.

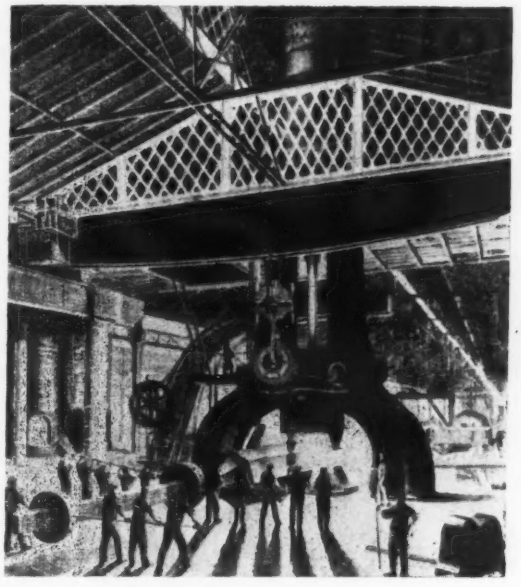


Fig. 2—Steam hammer at Marrel Frères Rive-de-Gier, 1892

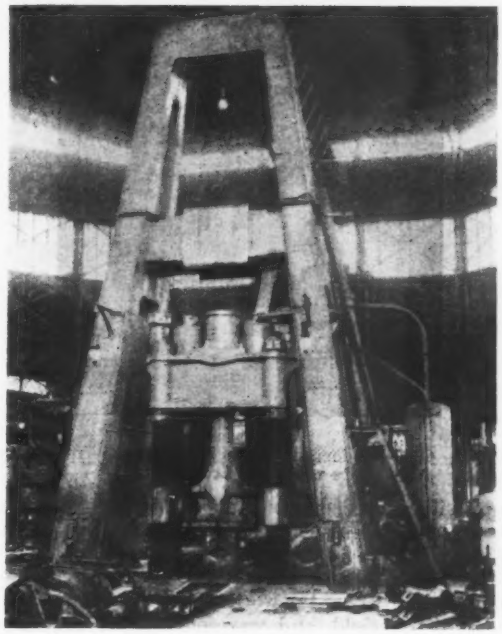


Fig. 3—4500-ton forging press installed by the Terni Company of Italy, erected under the legs of the 108-ton air hammer which it superseded

In 1886, Charles Davy, of Sheffield, introduced and patented what has since been known as the Davy Duplex forging press, the distinguishing feature of which was the introduction of a central guide stalk between the two main cylinders. Although more than 60 years have since elapsed, press constructors have not been able to improve on this principle of design, nor to find a better method of taking care of the forces arising from eccentric loading. In recent years, for example, leading constructors in Germany, such as Kreuser-Wagner and Schloemann, have embodied the central guide stalk in their most recent designs of 15,000 and 12,000-ton forging presses.

Figure 1 shows a sectional view of the cylinders of the 4000-ton Duplex forging press, as installed in 1886 in the works of what was then Charles Cammell and Company, in Sheffield. This press was soon to revolutionize the means then available for heavy forging, since it overcame the limitations of the giant steam hammers in use at the time. Figure 2 shows the last of these single-acting steam hammers which commenced work at Etablissements Marrel Frères, of Rive-de-Gier, in 1892, and was intended for ingots up to 125 tons.

The 4000-ton Duplex forging press was followed by several 2000-ton presses and then by presses of 4000 and 4500 tons' power. Figure 3 shows the 4500-ton press, installed by the Terni Company, of Italy, erected under the legs of the 108-ton air hammer

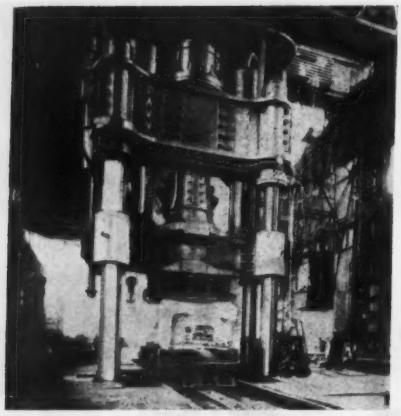


Fig. 4—6000-ton forging press installed at Wm. Beardmore and Co., Ltd., in 1934

which it superseded; as steam power was not available because of lack of coal, it was arranged for driving with water-turbine direct-driven pumps.

The first of the 6000-ton Duplex forging presses was installed in 1912 at the works of John Brown and Co., Ltd., of Sheffield, and was followed by four more 6000-ton presses for Japan, Russia, Czechoslovakia, and for Wm. Beardmore and Co., Ltd., of Glasgow. Figure 4 shows the press installed at Wm. Beardmore in 1934, and in spite of the long period between then and the time of installing the press at John Brown and Co., Ltd., in 1912, it was not found necessary to make any change in the design itself, except for the substitution of a more modern type of steam hydraulic intensifier of slightly larger capacity.

Construction

In considering any proposal for a new forging press, although the method of driving is of importance, the prime consideration is the construction of the press itself. The construction should incorporate:

(*a*) The most efficient system of guiding the moving crosshead, on which will largely depend favourable working of the main rams and their packings.

(*b*) Permanent rigidity of the whole press structure and ability to withstand the heavy working loads resulting from eccentricity and the heavy usage inseparable from heavy forging.

(*c*) The simplest possible lines consistent with efficiency, and the minimum number of wearing parts with surfaces of the largest possible area for resistance to wear.

From the list of presses in Table I, it will be seen that there are two main methods of construction: one method employs two main cylinders with a central guide stalk, and the other has three cylinders, with or without some form of guide stalk in the centre cylinder.

The different methods of driving the press will be discussed later, but it must here be mentioned that whether the press is to be designed with two or three main cylinders depends largely upon which of the following methods of working is employed:

(1) Steam hydraulic intensifier system (used for presses with two main cylinders).

(2) Pure hydraulic system, *viz.*:

(*a*) Electric pumps delivering direct into press with two main cylinders.

(*b*) Electric pumps with air-loaded accumulator and three main cylinders, giving three power stages.

(*c*) As (*b*), but with hydraulic intensification for a press with two cylinders and giving two power stages.

If the press is to be operated with electric power it will be necessary to decide which combination of design of press and method of driving will be the most satisfactory. If the direct pump system or the pump and air-loaded accumulator system with hydraulic intensifier is selected, then the press can function with two main cylinders, just as when worked with a steam-hydraulic intensifier, but the former would be the more economical, as the power consumed is directly proportional to the power exerted by the press, whereas with the latter there would be only two power stages, *viz.*, the lower one with the accumulator pressure and the higher one with the intensifier pressure. Three cylinders will be required if the press is to be worked with pump and air-loaded accumulator alone.

Figure 5 shows a 12,000-ton Duplex forging press constructed in 1939 for Russia. This press was to be worked with four steam-hydraulic intensifiers and at a later date, when electric power was available, the intensifiers were to be replaced by hydraulic pumps for working the press on the direct-pump system.

Figure 6 illustrates the Dortmund-Hörde 15,000-ton forging press designed by Kreuser and constructed by Wagner. This is also of the Duplex type, with two main cylinders and a central guide stalk, for working by hydraulic pumps and air-loaded accumulator, and presumably with hydraulic intensification, in which case it would operate as a two-power press, *viz.*,

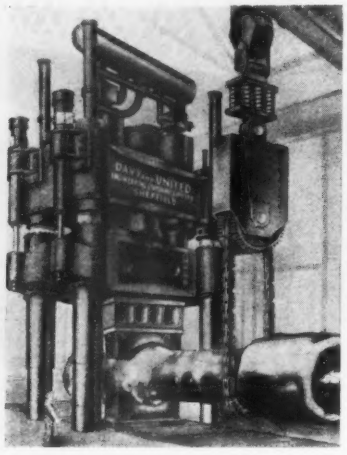


Fig. 5—12,000-ton Duplex forging press constructed for Russia in 1939

15,000 tons for upsetting and 5000 or 7000 tons for forging.

Figure 7 shows the 15,000-ton forging press, viewed from foundation level, built to Schloemann's design, for Russia, in about 1934. This press has three main cylinders, the two outside ones working with rams, and the centre one with a piston attached to the end of a central guide stalk, thereby introducing the central-guide principle in the construction of a three-cylinder press. The press is worked with steam-hydraulic intensifiers.

Figure 8 is a sketch of the arrangement of the upper part of a 12,000-ton forging press of a later Schloemann design, also with three main cylinders and a central guide stalk, but in this case all three cylinders are arranged for working with rams, the centre ram being made large enough to contain the central guide stalk. With pumps and air-loaded accumulator at a pressure of 300–350 atm. the two outer cylinders together exert a pressure of 4000 tons, the centre cylinder 8000 tons, and all three together 12,000 tons.

Figure 9 shows one of two 14,000-ton armour forging and bending presses built by the United Engineering and Foundry Company, of Pittsburgh, U.S.A., during the recent war. These presses are of a novel design in which the moving crosshead is guided

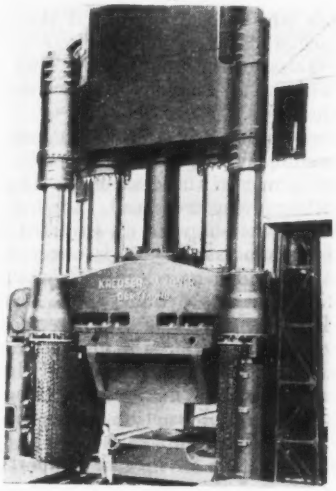


Fig. 6—15,000-ton forging press at Dortmund-Hörde

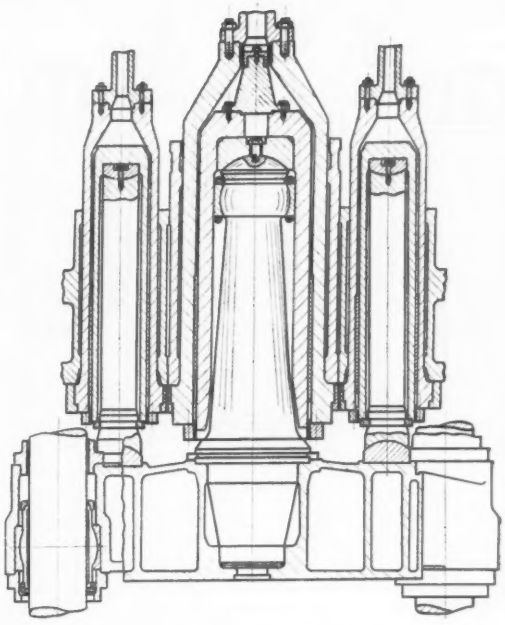


Fig. 8—Arrangement of the upper part of a 12,000-ton forging press of later Schloemann design than that shown in Fig. 7

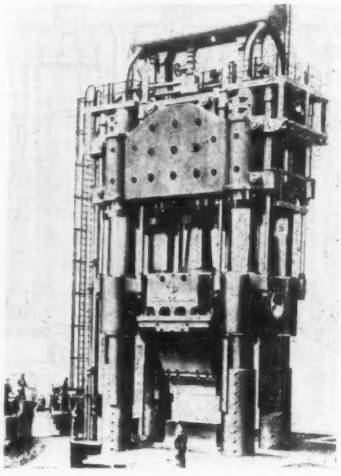


Fig. 7—15,000-ton forging press built to Schloemann's design for Russia (about 1934)

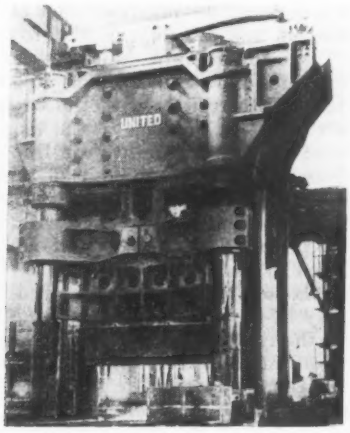


Fig. 9—14,000-ton armour forging and bending press, built by United Engineering and Foundry Company, Pittsburgh, U.S.A.

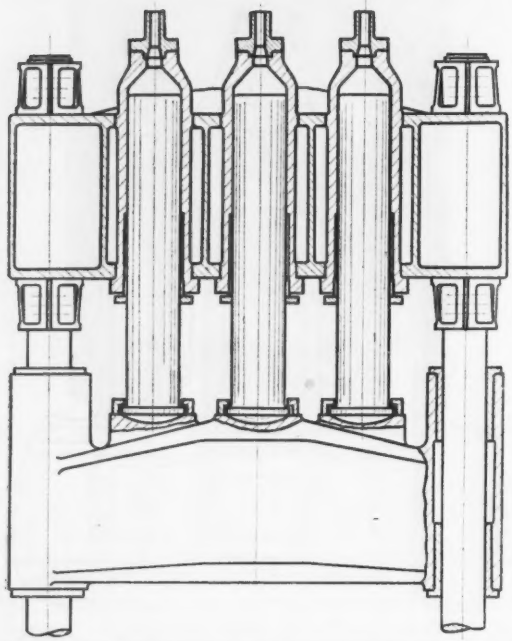


Fig. 10—Arrangement of cylinders and moving crosshead of 15,000-ton Krupp forging press

by its stalk in the entablature between the two main cylinders, entirely independent of the press columns. It is claimed that full load can be exerted as much as 4 ft. from the centre in the case of one press, and as much as 6 ft. in the case of the other, without seriously deflecting the superstructure of the press. One of these presses is worked with steam-hydraulic intensifiers, and the other on the pump and accumulator system.

It is a special feature of the new type of guide stalk that no side load is transmitted from the crosshead to the columns, and theoretically no crosshead column bushes are required. In practice, such bushes are fitted to function in a direction parallel to the short centres of the columns only, in case wear on the guide stalk should allow the top tools to get out of line and thus fail to register with the bottom tool. In the other direction, parallel to the long centres of the columns, the guide bushes are free to float. The stalk itself is a built-up unit of rectangular section fitted with wearing plates. Renewable plates are also fitted in the entablature, and with this type of guide, the press deflection under full out-of-centre load is reduced to $\frac{1}{8}$ in.

Owing to the shorter out-of-centre distance specified, the duty of the 14,000-ton press at Midvale is less onerous than that of the South Charleston unit, and the various main members were made somewhat lighter. The column centres are the same for both, 23 ft. 0 in. × 11 ft. 6 in., and each has a daylight above floor level of 22 ft., with a working stroke of 10 ft. at South Charleston and 9 ft. at Midvale.

Figure 10 shows the cylinder arrangement and moving crosshead of the 15,000-ton Krupp forging press, in which the power is obtained by three main cylinders of 40 in.; the moving crosshead, which is made exceptionally deep, is guided on the columns alone. The press is also driven with a steam-hydraulic intensifier.

Figure 11 shows the arrangement adopted for the 8000–12,000-ton combined forging and bending press at Terni, Italy, in which again the power is obtained from three main cylinders. For armour-plate bending, the upper and lower crosshead guide bushes are removed to enable the crosshead to tilt upon the central spherical pads, and this arrangement ruled out the central guide stalk design.

Influence of Design upon Method of Driving

The central guide forging press is generally well known to the older press executives, but the younger generation may well ask why the choice between the two methods (the direct pump, and the pump and air-loaded accumulator without hydraulic intensifier) affects the design of the press itself. This cannot be answered without an analysis of the constructional details of the press.

In a heavy forging press, provision must be made for withstanding heavy eccentric loads, and this requirement is met in the case of the Duplex press by making the moving crosshead, carrying the upper forging tool, in the shape of an inverted **T**, with a vertical member, or stalk as it is commonly called, contained and guided in a central cylinder, power being obtained by two cylinders, one on each side of the horizontal member of the inverted **T**. This type of crosshead also offers the maximum resistance to the heavy bending moment set up when forging out-of-centre up to 15 in. in either direction, with the minimum of horizontal reaction on the press superstructure, inasmuch as the load set up on the end of the crosshead stalk is in inverse proportion to its length.

Other important characteristics of this construction are that it permits the use of only two main hydraulic

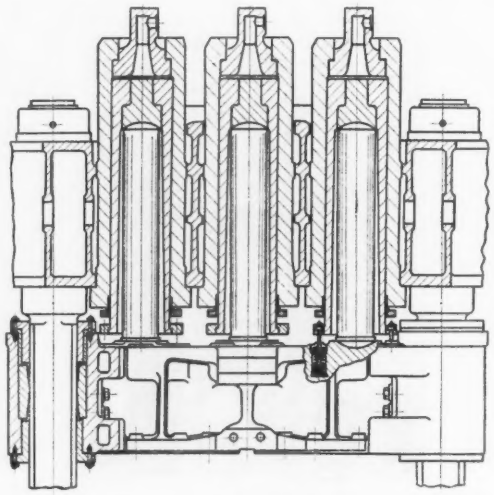


Fig. 11—Arrangement of 8000–12,000-ton combined forging and bending press at Terni, Italy

cylinders and the location of the guide stalk in the centre, a feature which enables the width of the entablature to be kept narrow, thereby giving the closest possible approach to the press of the burden chain supporting the forging. The reduction in the width of the entablature is assisted by making the diameter of the main cylinders as small as possible by using high-pressure water at 3 tons/sq. in.

It can be seen from further comparison that the direct pump system can be employed without sacrificing any of the essential features mentioned in the construction of the press itself. With the pump and air-hydraulic accumulator system, without intensification, the case is quite different, for the following reasons :

(1) Hydraulic cylinders of larger area are required because of the limiting pressure (say, 2·35 tons/sq. in.) of an air-hydraulic accumulator.

(2) If economy in hydraulic power is to be achieved with, say, a 12,000-ton press, three fixed power stages of 4000, 8000, and 12,000 tons are required for varying the power of the press because the working pressure is constant.

These factors afford some measure of economy, but only partially, as compared with that possible with the direct pump system. If, for example, the 8000-ton power stage must be used for forging at 5000 tons—too great a load for the lowest power stage—power is wasted. As the 12,000-ton stage will be used mainly for upsetting operations, and then only occasionally, the bulk of the work will be done with the 4000- and 8000-ton power stages, and it is reasonable to assume that the 8000-ton power stage will be used for the greater part of the time. On the other hand, with the direct pump system the power consumption is directly proportional to the power exerted, and is therefore the most economical.

It must next be considered how the press can be worked with three hydraulic cylinders and still retain the inverted-**T** moving crosshead. The vertical guide stalk can be retained in the case of the press worked with pump and accumulator only by dispensing with the central guide cylinder and substituting in its place a hydraulic cylinder with a hollow ram large enough to contain the vertical guide stalk in its interior. The stalk is too large to be accommodated in the ram of a cylinder of less than 8000 tons' power, so the two remaining cylinders must each be of 2000 tons' power, made so that the first pressure stage of 4000 tons will be obtained from the two outer cylinders, the 8000 tons from the single middle cylinder, and the 12,000 tons with all three cylinders.

As already mentioned, one of the objects of the Duplex design was to maintain a narrow press head or entablature. With two 51½-in. dia. cylinders working at 3 tons/sq. in., the press head is as narrow as 10 ft. 10 in. ; with the central 8000-ton cylinder of about 67 in. in dia., and with two 2000-ton cylinders about 47½ in. in dia., working at 2·3 tons/sq. in. pressure, in the three-cylinder press, the width must be increased to 13 ft. (an increase of 2 ft. 2 in.), which is a serious disadvantage.

A further disability is caused by eccentricity. For example, the calculated horizontal force in the 12,000-ton Duplex press forging 15 in. out-of-centre is approximately 745 tons. This limit of distance should not be exceeded, but in actual practice, especially when handling large forgings, it is impossible to keep within such a close distance and the force mentioned is on occasions considerably exceeded. In the case of the Duplex or two-cylinder press, this horizontal force is taken by the head of the stalk sliding in its own guide cylinder. As a result of experience gained in the reconditioning of forging presses which have been working for a considerable time and in which considerable wear has taken place in the guide cylinder, it is now standard practice to fit a spherical self-aligning head to the stalk, with arrangements for its automatic lubrication.

The common belief in the past has been that the chief cause of wear is the horizontal thrust due to the forging being out-of-centre in the sideway direction, but experience gained in the course of reconditioning forging presses has shown that the greatest amount of wear in the guide cylinder is in the front and back direction. This is due apparently to the thrust on the face of the tool as it bites in the forging, and takes place with each stroke of the press and not only occasionally when working out-of-centre. Admittedly, such thrust is less in magnitude, but the effect on the press as far as wear is concerned is greater, as it occurs with almost every stroke. It is for this reason that in presses of recent construction, special provision has been made for the continuous lubrication of the self-aligning head on the guide stalk.

This feature cannot be adopted in the case of the three-cylinder press, in which the stalk is contained inside the central ram, as, although the diameter of the ram may be large enough to resist the thrust, the absence of any means of effectively lubricating the cylinder wall—apart from the small amount of soluble oil contained in the pressure water which is inadequate for effective lubrication—is an aspect open to criticism.

METHODS OF DRIVING

The most suitable method of driving depends on whether the press is to be worked with two or three cylinders. Opinions are naturally divided on the relative merits of the direct pump system and the pump and air-hydraulic accumulator system, but there can be no doubt that the two-cylinder press is the more simple, and has the more acceptable construction ; furthermore, the system employing direct pumps is more simple than the pump and air-hydraulic accumulator system, either with or without intensified pressure.

Steam-Hydraulic Intensifier System, with Two Main Cylinders

This system, by reason of its simplicity and elasticity of operation, has been regarded as the most adaptable for the needs of the forgeman, but with the increasing use of electric power the era of the steam-hydraulic intensifier is closing, and it is being superseded by the pure hydraulic system of driving. Yet many claim that with it they can forge faster and get more work out in a heat than with any other method of driving. Consequently, it would be inappropriate to pass over this system without some reference and description.

Being equally applicable to all powers of presses, this system has been generally adopted as standard, particularly for the lesser and medium powers. With work that is well within the capacity of the press, the penetration is most rapid on long cogging strokes, and on light, finishing strokes, more strokes per minute are possible than with any other system. For example, on 6000-, 4000-, and 1000-ton presses, finishing strokes up to 50, 80, and 90 per min., respectively, have been attained with perfect control, safety, and ease of handling, when equipped with an efficient controlling gear.

A notable example is a press installed at Canton, Ohio, U.S.A. This is used for breaking down squares to form round bars of about 3½ in. in dia., and it was reported to be making as many as 134 strokes per min., a striking example of the possibilities of the steam-hydraulic intensifier system. However, although a penetration of the forging of 3 and 4 in./sec. is easily obtainable—provided that the forging is well within the useful capacity of the press—the speed diminishes as the resistance of the forging approaches that of the power of the intensifier. Consequently, the average size of work forged with this system should be kept well within the useful capacity of the press, and should not require more than two-thirds of the full power for forging strokes and not more than half power for finishing strokes.

Loss from condensation, inevitable with intermittent operation, has given the steam intensifier the reputation of being wasteful of steam, so it is not regarded as an economical unit in itself. But since the cost of power represents only a very small part of the total cost of the forging, it has generally been regarded that its inefficiency in steam consumption is more than counter-balanced by the greater amount of work it is capable of putting in a forging during a heat, which, after all, is the real measure of efficiency and economy. For example, the 12,000-ton forging press built for the U.S.S.R. (shown in Fig. 5) was arranged for driving with four steam-hydraulic intensifiers, with steam cylinders 95 in. in dia. and a stroke of 10 ft., working with a steam pressure of 150 lb./sq. in. and a back pressure of 30 lb./sq. in., making the pressure available only 120 lb./sq. in. Because the intensifier dimensions indicated represented the maximum sizes possible, as regards manufacture and transport, four such intensifiers were provided, arranged in one row and controlled from a common way shaft through a steam relay gear by a single driving lever, the control being arranged so that when the press was operating at its lowest power two of the intensifiers could be cut out. This installation of steam intensifiers is of particular interest as each one was arranged with three hydraulic cylinders, *viz.*, one large central and two smaller side ones, with valve control enabling the centre one and the two side ones, or all three, to be worked independently or together, thus :

(1) Central intensifier ram only : 12,000 tons, movement on the press 12 in.

(2) Two side rams only : 8000 tons, movement on the press 18 in.

(3) All three rams : 4750 tons, movement on the press 30 in.

The press was guaranteed to work at the following speeds :

(1) At 12,000 tons' power : 5 pressing strokes per min., 6 in. penetration ; 20 finishing strokes per min., ¾ in. penetration.

(2) At 8000 tons' power : 30 finishing strokes per min., ¾ in. penetration.

(3) At 4750 tons' power : 40 finishing strokes per min., ¾ in. penetration.

These numbers of strokes were to be obtained working at not more than two-thirds of full power when actually forging, or at not more than half power when finishing. The idling speed was 12 in./sec. ; an auxiliary pre-filler was provided immediately over the fill-up valve and main cylinders to make such idling speed possible with the minimum shock.

Pure Hydraulic System

(a) *Electric Driven Pumps, Delivering Direct into a Forging Press with One, Two, or Three Cylinders*—In considering a new forging-press project, there is a choice between two electric hydraulic systems, with or without an intensifier in addition. Where all forging requirements can be met by one or more pumps alone, the direct pump system is to be preferred. It is generally admitted to be the most economical method of driving, as the power absorbed in driving the pumps is little more than that required to overcome the resistance of the forging. The valve system for controlling the working of the press is simple, and requires little attention. As there is no bank of accumulator bottles, and the pumps only number one or two large units, this system involves little mechanical and electrical maintenance. Large pump units now give excellent working conditions and are just as reliable and efficient as any modern electric generating plant. In the case of the direct pumps, two methods of driving are employed. The first is exemplified by the system in use on the 7000-ton press at the works of the English Steel Corporation, Ltd., Sheffield.[2] The single pump is driven by a 2500-h.p. motor assisted by two high-speed flywheels on the reduction-gear set to meet peak-load conditions, and is equivalent to about 6500 h.p. An example of the second type of drive is to be found at Terni.

In about 1935, an 8000–12,000-ton combination forging and bending press was installed at Terni, the cylinder and guide arrangement of which is shown in

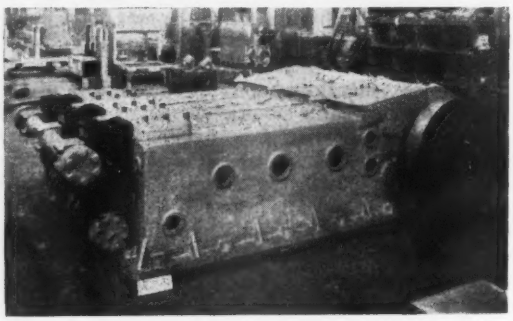


Fig. 12—A forging pump of recent construction (Elswick design)

Fig. 11. The motors are coupled direct to the two sets of pumps, and are supplied with power from an Ilgner group, on the same lines as in modern rolling-mill drives. The coupling of the motors direct to the pumps, and the transmission of the power through the magnetic field of the armatures and stators of the motors, make an ideal drive for forging, giving smooth and quiet running with freedom from shock, and the Ilgner system provides the utmost degree of flexibility in both speed and control; the pumps can work the press at any speed and can run intermittently or continuously to suit the work being done under the press. Figure 12 shows a forging pump of recent construction.

Control Gear—The control employed with the direct pump system is of the simplest possible character, consisting in general principle of a forging valve, fill-up valves, and a lifting valve. In this arrangement the main, or forging, valve is subject to pressure only whilst the press is actually squeezing, and consequently it requires little attention.

With the press standing and pumps running and the driving lever in mid-position, the forging valve is open, allowing delivery from the pumps, which are kept running during the heat, to circulate back to the pre-filler from which the pumps take their suction. The lifting-cylinder pressure and exhaust valves both remain closed. To lift the press head the lever is pulled back and pressure is exhausted from the top of the lifting cylinders, allowing the constant pressure under the pistons to lift, the water from the main cylinders passing out through the fill-up valves and through the open forge valves back into the pump circulation. To make a pressing stroke, the top of the lifting cylinders is opened to pressure for the descent of the main rams, and the fill-up valves are opened partly by the movement of the hand lever and partly automatically. The forward movement of the hand lever closes first the fill-up valves and then the forge valve, thereby putting the pumps into direct communication with the main cylinders. The reverse movement of the hand lever opens first the forge valve, then the fill-up valve, and the top of the lifting cylinders is opened to exhaust; the constant pressure under the lifting piston then forces the water from the main cylinders back through the fill-up valves and partly through the forge valves into the air vessel or pre-filler.

The following may be taken as a typical example of the pumping equipment for a 12,000-ton Duplex forging press of sufficient power to make six 10-in. full-load strokes per min. and a greater number of shorter strokes, equal to the speed with which the forging can be manipulated, and giving a speed of penetration with two pumps of about $2\frac{1}{4}$ in./sec., an average speed proved to be the most suitable for a press of this power:

Two horizontal three-throw hydraulic pumps with rams $6\frac{3}{4}$ in. in dia. and stroke 33 in., delivering up to a pressure of 3 tons/sq. in., and a speed of up to 90 r.p.m.

Displacement of each pump 19 gal./sec.

Actual delivery about 17 gal./sec.

Power of motors directly coupled to each pump, R.M.S. rating, each 4000 h.p., with peak output 6000 h.p.

Speed of motors 0–90 r.p.m. The Ilgner group for supplying the two pump motors consists of an induction motor of 8000 h.p. and four D.C. generators each of 1500 kW., total 6000 kW.

Hydraulic pumps for operating the lifting cylinders and floor gears would comprise four pumps each of 220 h.p. and an air-hydraulic accumulator of 400 gal. capacity, with a working pressure of 3000 lb./sq. in.

(b) *Electrically Driven Pumps and Air-Hydraulic Accumulators*—Like the direct pump system, the system employing electrically driven pumps and an air-hydraulic accumulator, is not without certain distinct advantages, and is regarded as the nearest equivalent to the steam-hydraulic intensifier system, in the sense that one makes its forging stroke by taking a large volume of steam from the boiler, and the other takes a similar volume from the water stored in the accumulator. Consequently it is not only able to make the same length of forging stroke at a similar speed of penetration, but it also has the advantage of being able to make the stroke continuously up to the limit of the capacity of the accumulator. With the increasing use of electric power, it is becoming well established for forging presses of moderate power and for special presses for work of a repetition nature, such as wheel forging, etc., for which it is eminently suitable, working in conjunction with a hydraulic intensifier.

The hydraulic pressure with the air-hydraulic system is limited to below $2\frac{1}{2}$ tons/sq. in., as above this limit the air and water cannot be kept separate. Where heavy forging presses take their supply from an accumulator at this pressure, they must be arranged to work at one-third, two-thirds, or full power, and must consume power for their operation in that proportion, in order to obtain any measure of economy of power consumption.

With the air-hydraulic system, a certain amount of the pump delivery is being stored up in the accumulator in the intervals between the pressing strokes; hence the total power of these pump units is less than with the direct drive, but the energy actually necessary for the deformation of the forging is the same whether the pumps deliver direct or through an accumulator. It simply means that the accumulator pumps, if they are of less power than the direct pumps, will be in motion for a longer period. Although accumulator pumps can be arranged to stop running when the accumulator is full, users generally prefer to run the pumps continuously, by-passing water when not under load; consequently the energy consumption when running under no-load may be regarded as about the same with both systems. Actually the Ilgner drive enables the direct pumps to be slowed down to creeping speed during the time in a heat when the press is not actually forging, or they can be stopped and started just as in the case of a reversing rolling mill.

The attention and servicing necessary is considerably more with the pump and air-hydraulic system than with the direct pump system, since there are the reduction gears, by-pass valves, and delicate instruments and controls to get out of order. In view of this it may be asked, why the pump and air-hydraulic system has been favoured by certain forging-press makers in Germany. One of the principal reasons is, no doubt, the advantage of constituting

what might be termed a central water-power station, available for servicing a group of presses, the capacity of which would be readily increased by adding more pumps and air and water bottles as the demand increased. Also, the system lends itself to being built up from a number of relatively small units or parts, which can be made by a number of firms, and it provides the easiest way of building up a driving unit for any size of forging press.

(c) *Electric Pumps with Air-Hydraulic Accumulator and Hydraulic Intensification*—The system incorporating electric pumps with an air-hydraulic accumulator and hydraulic intensification, enables the pump and air-hydraulic system to obtain two power stages from a single main cylinder by the addition of a hydraulic intensifier, and it is therefore most applicable for forging presses of medium powers. For example, a forging press of 2000 tons' power could exert 1000 tons' power when working direct from the accumulator with a pressure of 3000 lb./sq. in., and 2000 tons with the pressure intensified to 6000 lb./sq. in. This provides an appreciable measure of economy, as a considerable proportion of the product may be within the capacity of the lower power stage.

The system is applicable to heavy forging presses which can be worked as two-stage presses. However, the dimensions of the hydraulic intensifier would become very large, and a great deal of maintenance would be necessary, particularly when a long stroke at full power is required. Hence it is justified only when the work is of a special nature. For example, in a 6000-ton wheel-forging press, recently completed, used for slabbing and punching sliced ingots, all the pressing stroke is effected with an accumulator pressure of 3000 lb./sq. in., exerting 3000 tons, except for the last portion when the hydraulic intensifier is brought into action. For work of this kind on a single-cylinder press, this particular system is ideal.

Types of Press Drive in the U.S.A.

As will be seen from the remarks given in the review of American presses (Table I), the process of evolution in press drives that has occurred in this country has also taken place in the U.S.A. The early presses were driven by steam pumps, which were later displaced by the steam-hydraulic intensifier, and this is now being partly superseded by the electrically driven pumps, although in the American heavy forging presses an air-loaded accumulator has also been used. The pump drive without an accumulator has been adopted on some smaller units.

The reasons for the tendency to change over to the electrically driven pumps, with or without an accumulator, are the same as those which apply in Great Britain, namely, the lower cost of electrical power as compared with the cost of raising steam, and the ability to reduce stand-by losses during pauses by stopping the pumps. With the steam intensifier, it is, of course, essential that a head of steam be maintained continuously, if there is any possibility of the press being required.

Types of Pump—A comparison of the two 14,000-ton presses at South Charleston shows that, whereas the United press is fitted with reciprocating pumps, that built by the Mesta Machine Company has centrifugal pumps; this type of pump is now their standard practice. For the 14,000-ton press, three centrifugal pumps are arranged in tandem so that each forms one stage of a three-stage pump, with a pressure difference through each pump of 1850 lb./sq. in. The three pumps are individually driven at motor speeds of 3600 r.p.m., and they form very neat and compact units of comparatively low cost. A further advantage is that, owing to the pump characteristics, the delivery falls to zero at a point somewhat above the normal working maximum, and the control gear necessary to unload the reciprocating type of pump, when the air-hydraulic accumulator is full of water, is not required.

A certain measure of economy in pressure water can be obtained, when full press power is not required, by cutting out the last pump and operating the press at two-thirds of the rated pressure. The accumulator itself appears to be comparatively small for the size of press, and it seems that at least one of its main functions is to provide a hydrostatic head for the pumps and thus help to maintain their operating efficiency. On the other hand, the efficiency of a high-pressure centrifugal pump is low—about 70% as against the 90% or more obtained from the reciprocating type—but even more important than this, in view of the large proportion of idling time, is the fact that idling losses are 40% or more, compared with the 5 to 10% of the reciprocating pump. This difference will more than wipe out the advantage of low first cost, and it must also be remembered that the energy thus absorbed reappears as heat, for the removal of which some form of cooling equipment has to be provided. The balance of advantage would therefore still appear to be with the reciprocating pump.

A Comparison of Operating Costs of Steam and Electric Drives in the U.S.A.

The installation, at almost the same time, of two very similar 14,000-ton presses by the United Engineering and Foundry Company, one having a steam intensifier drive and the other using reciprocating pumps and an air-loaded accumulator, enabled some very valuable and interesting data to be obtained. This information has been published[3] and covers a period of two years. It shows that the cost of the steam used per operating hour, including labour charges at the boilers, was $18.50, and that for the electrical power was $5.63, or less than one-third. Repair and maintenance labour costs were practically the same in each case, but the charges for repair and maintenance supplies were greater in the case of the pump drive than with the steam intensifiers. Even after allowing for this, the total cost per operating hour for the pump drive was $15.53 as against $21.60 for the steam intensifier drive, and this saving is estimated as being about 7% on the total cost of labour, fixed charges, and administration.

In each case, the presses were working two and three shifts, averaging about 570 hr. per month, of which about 50% was actual forging time. An interesting point is that the average power used over a period for each type of drive is only about 15%

of the maximum demand, equivalent to 85% of idling time.

DETAILS OF CONSTRUCTION

The following details of construction relate to the 12,000-ton Duplex forging press supplied to the U.S.S.R. in 1939, which is selected as a typical example of a modern heavy forging press.

The Press Base

How long the structure of any heavy forging press will remain rigid and free from movement depends largely on the construction of the base of the press, and the permanent solidity of this is largely dependent on the way in which the component castings are held together.

Figure 13 shows the base assembly of the 12,000-ton press. The joints are secured by short bolts, tightened by shrinkage, and a series of high-carbon steel folding keys are fitted in grooves planed across the joint faces, thereby securing absolute metal-to-metal contact without any tolerance. With such construction the joint bolts are relieved of shear stress, and the absolute solidity thus obtained ensures immovability of the joints. These joints, which were used in an older press, have never required any attention and remained tight even though the columns, being fitted with nuts between the base and entablature, worked themselves loose and developed a slight lift, in the course of over thirty years.

In recent years some makers have adopted a construction in which the main members are held together at the top by long links and at the bottom by a few large-diameter tie bolts.

In comparing these two methods of construction, it will be generally agreed that there is less extension under load in a short bolt than in a long one, and consequently there is a greater tendency with the latter for the joints to lose their original tightness, allowing them to chafe and wear ; this, together with the effects of water and corrosion, causes the whole assembly to become loose. To some forge engineers this latter construction may have the appearance of being of a more modern character, but in the authors' opinion its value can be proved only by the test of time.

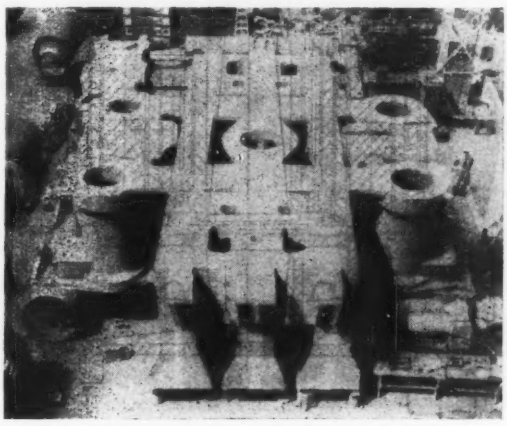


Fig. 13—Base assembly of 12,000-ton forging press

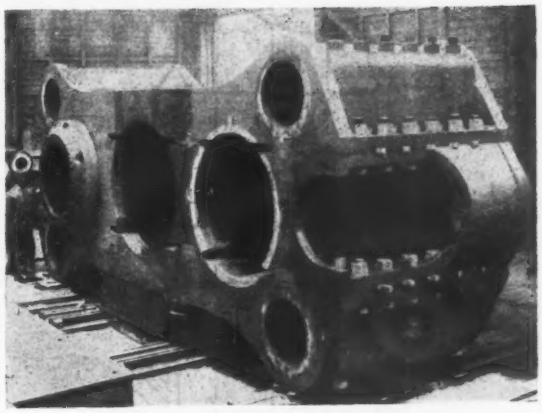


Fig. 14—Entablature of 12,000-ton forging press

Figure 14 shows the entablature of the press constructed in a similar manner to that of the base, the main cylinder flanges being carried directly on the two longitudinal and the four transverse tie members ; this arrangement enables the width of the entablature to be made as narrow as 10 ft. 10 in., thereby giving the closest possible crane approach.

The corresponding dimension in the 12,000-ton three-cylinder press, shown in Fig. 8, is 13 ft., as the cylinder is contained between the two main members in box-shaped castings. Flanges on the base of the boxes are made to lip over and register with the lower flanges of those main members and are further secured to them by a number of vertical bolts. The upper part of the entablature is held together by two heavy tension bolts, thereby, perhaps, simplifying the construction from a manufacturing point of view, but such an arrangement is open to the serious objection that, even assuming that the lipped joints are machined and made an accurate fit—an uncertain matter with castings of such size—the tolerance necessary to assemble the parts is sufficient to allow, in the course of time, a gradual increase with the deflection of the component parts under the action of their working stresses. The authors cannot see how such an assembly can be expected to hold together for any length of time without some movement, and it is therefore a construction that they would hesitate to adopt.

The Columns

Next in order of importance are the columns. Those in the 12,000-ton forging press shown in Fig. 5 are of hollow construction, and details are as follows :

Internal dia.	...	...	24 in.
External dia.	...	...	41 in.
Length ...	...	...	64 ft. 3½ in.
Weight ...	...	...	92 tons

The use of hollow columns is a comparatively new feature in heavy forging press construction ; it ensures a forging of better quality than if made solid, and a stiffer section, with increased resistance to bending, can be obtained for the same weight.

The columns are of Siemens-Martin low-nickel steel,

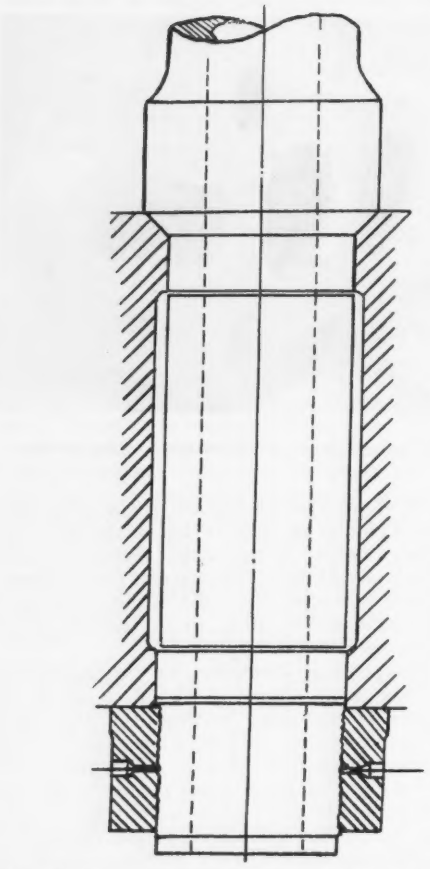


Fig. 15—Detail of column end of 12,000-ton forging press, showing method of attachment to baseplate

hollow-forged from ingots of 230 tons' weight, normalized, and heat-treated to a tensile strength of 40 tons/sq. in. and a minimum yield point of 22 tons/sq. in. They are seated on the base, as will be seen from Fig. 15, on coned collars instead of flat faces, and are pre-stressed on the length between the collars and the bottom nut by controlled contraction to an amount in excess of the maximum press load ; consequently there is no separation of collar and nut surfaces from the base when under load. The coning of the collars to an angle of 45° effectually prevents the setting up of any chafing movement. Such a construction ensures a high degree of tightness and permanent rigidity of the press structure as a whole.

The Crosshead and Guides

The moving crosshead in this construction is built up of four steel castings, *viz.*, body, stalk, and two end guide brackets each fitted with two cast-iron guide bushes, making the effective length of each guide 10 ft. The upper end of the stalk is fitted with a ball head, which makes the guide piece self-aligning in the guide cylinders, and as it is subjected to heavy pressure when forging out-of-centre, it is lubricated continuously, as are the guide bushes on the columns,

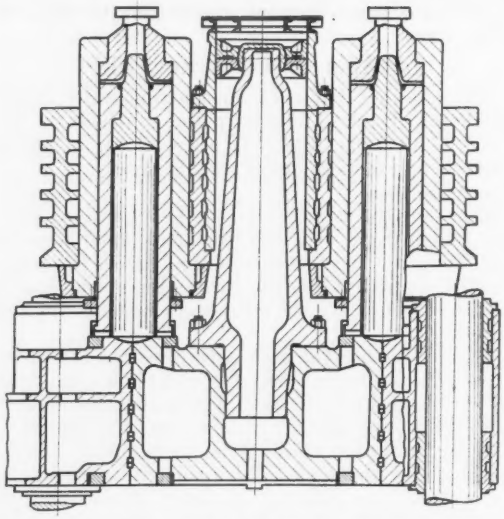


Fig. 16—Upper part of 12,000-ton forging press

by electrically driven grease pumps mounted on the moving crosshead. Figure 16 shows the arrangement for a 12,000-ton press, and Fig. 17 that adopted by another maker on a 15,000-ton press, the guides being self-aligning and connected to the crosshead by ball-ended extension arms. Figure 7 shows another arrangement in a 12,000-ton press in which the guides are made self-aligning by being contained in spherical seatings.

Self-aligning guides have the advantage of enabling more equal distribution of pressure on the column, but they introduce additional parts which are subject to wear, resulting eventually in slackness and allowing

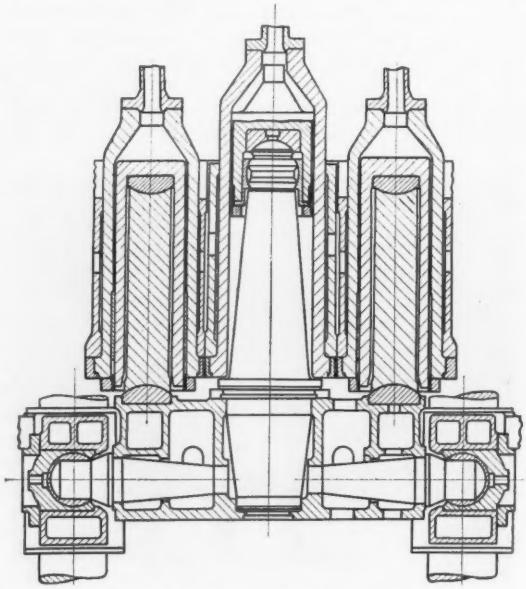


Fig. 17—Self-aligning guides on 15,000-ton forging press

the crosshead to tilt. A further, and more serious, disadvantage is that the resistance of the columns to the tilting of the crosshead is reduced. With self-aligning guides the thrust of the guide on the columns when forging out-of-centre is in one direction ; with rigid guides it is in two directions, inwards at the top and outwards at the bottom (or *vice-versa*, according to which side of the press the forging is out-of-centre), with the result that the moving crosshead receives a greater support from the columns.

Main Rams

The main rams are made hollow, with internal thrust rods with spherical ends, instead of being directly or rigidly connected to the crosshead, in order to safeguard them from the heavy lateral force resulting from eccentric loading ; this provides an indirect flexible connection ensuring freedom from excessive wear or side pressure on the ram packings. It is only by such provision that the rams are able to work for long periods without leakage or replacement.

THE MANIPULATING GEAR

The arrangement of the manipulating gear and its accessories for quick and efficient manipulation is of the utmost importance. In the 12,000-ton forging press shown in Fig. 5, the base of the press is surmounted with substantial bedplates which carry a three-part sliding table, 13 ft. wide and 33 ft. long, for carrying the bottom forging tool and the stools for supporting the mandrels when hollow-forging by expanding. Such a table is a comparatively new feature in forging-press construction. The surface is level with the floor, parts of which are made to move with the table, so that all sliding surfaces are covered and as free as possible from scale and water. This arrangement of floor dispenses with the trenches at the front and back of the press, customary in presses of earlier construction, although still preferred by

Fig. 19—Projector unit (viewed from below)

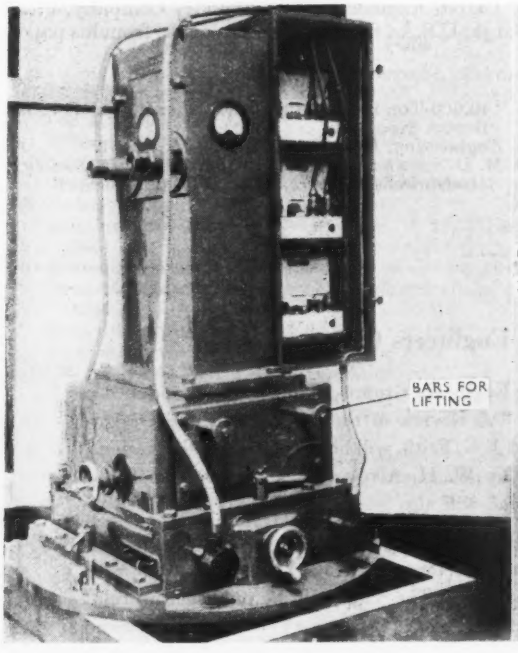


Fig. 18—Photo-electric receiving unit

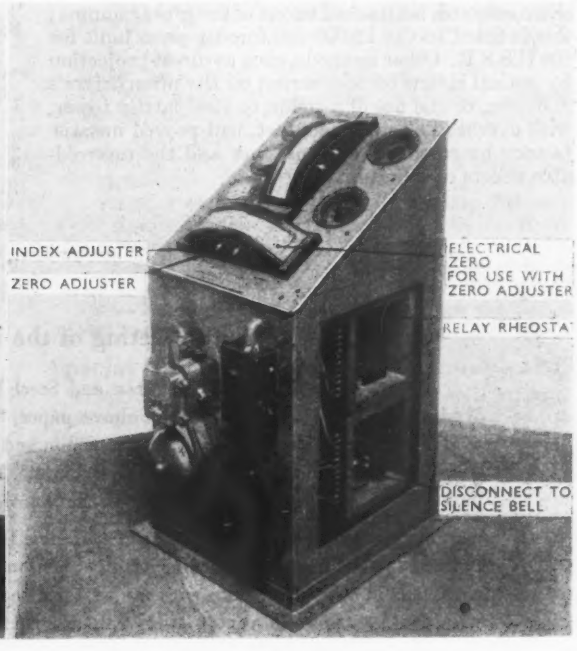


Fig. 20—Control desk

some press users. In this new construction the table sides are strongly lipped over the edges of their supporting bedplates and provide a much more substantial attachment than is possible with short mandrel supports sliding between slide curb guides.

It cannot be too strongly emphasized that all manipulative accessories should be exceedingly strong, of simple design, and readily maintained. With these objects in view, the best arrangement is that in which two stationary ram cylinders are situated on each side of the press so that the outer positions of the three-part sliding table or anvil plate can be manipulated independently of each other.

The hydraulic cylinders should be arranged in tandem, so that by removing the floor-covering plates they can at once be inspected and glands repacked.

Although forging tools can be easily changed by using the manipulating gear, transverse tool-changing gear is of advantage, and in fact is necessary for positioning the ingot in the direction of the narrow way of the columns previous to upsetting. In the forging of rectangular or slab ingots, too short to be handled by the cranes, they can be manipulated and fed through the press by the addition of hydraulic slabbing gear, consisting of an arrangement of lifting arms and stools on each side of the press, the arms being pivoted on brackets attached to the outer sliding tables, with the front ends resting on rollers and lifted by hydraulic cylinders.

COLUMN DEFLECTION INDICATOR

To ensure protection from the effects of forging too much out-of-centre, a new method has been devised and patented in which the apparatus, completely self-contained, is attached to one of the press columns ; this is fitted to the 12,000-ton forging press built for the U.S.S.R. Other methods, such as direct projection by optical means on to a screen on the press driver's platform, or the use of a pylon or steel lattice tower, with overhead electrical contact, had proved unsatisfactory by reason of encumbrance and the unavoidable effects of vibration.

The apparatus on the 12,000-ton press comprises three units :

(1) An optical projector fixed to the lower end of the column (shown in Fig. 19), which throws two beams of light up the hollow column.

(2) A photo-electric receiving unit fixed at the top of the column, as shown in Fig. 18.

(3) A control desk on the operating platform on which the deflection is indicated, shown in Fig. 20.

The photo-electric receiving unit functions through amplifiers which in turn indicate the reflection on to edge pattern volt-meters on the control desk. These show the deflection in two meridians at right-angles, consequently showing the movement of the press head from side to side by the movement of the finger from the zero position in either direction on one meter and similarly on the other volt-meter from front to back of the press.

In addition to indicating the movement on the volt-meter scales, the apparatus is arranged so that if the deflection exceeds a predetermined limit in the side to side or front and back direction or a predetermined resultant of these two directions, then in any one of these three positions an alarm will be sounded to warn the driver that the press is being overloaded. The control desk containing the volt-meter indicators, etc., is arranged for mounting on the press platform immediately in front of the press driver.

Acknowledgments

The authors wish to thank the Directors of Davy and United Engineering Co., Ltd., Sheffield, for permission to publish this paper, and Dr. M. D. Stone, of United Engineering and Foundry Company, Pittsburgh, U.S.A., for permission to quote from his paper.

References

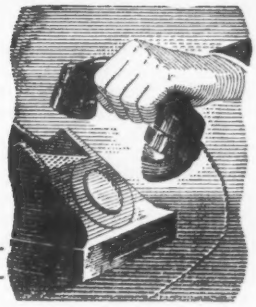
1. "40,000-Ton Forging Press and Other Plant." B.I.O.S. Report No. 1102.
2. *Engineering*, 1935, vol. 134, Feb. 15, p. 161.
3. M. D. STONE : *Transactions of the American Society of Mechanical Engineers*, 1948, July, pp. 499–514.

Ninth Meeting of the Engineers Group

At the Ninth Meeting of the Iron and Steel Engineers Group, to be held in London on Wednesday, 23rd March, 1949, the above paper, "A Review of the Application and Design of Heavy Forging Presses," by J. A. Sanderson and J. G. Frith, will be presented for discussion. The paper, "A Modern Heavy Forging Plant," by W. H. Alvey, which was published on pages 119–138 of the February issue of the *Journal*, will also be discussed.

The manuscript of a third paper, "Heavy Forging Manipulators," by A. V. Flinn, will not be received in time for publication in the *Journal* before the meeting and the author will present it in shortened form, with a film, for discussion. The paper will be published in full, with the discussion, in a later issue of the *Journal*.

N E W S



ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE

Annual General Meeting, 1949

The Annual General Meeting of the Institute will be held on Wednesday, 27th April, 1949, in the Lecture Theatre, Central Hall, Westminster, London, S.W.1, and on Thursday, 28th April, 1949, at The Institution of Mechanical Engineers, Storey's Gate, London, S.W.1.

A Buffet Luncheon will be available in the Library, Central Hall, Westminster, on Wednesday, 27th April.

A Members' Luncheon will be held at the Dorchester Hotel, Park Lane, London, W.1, on Thursday, 28th April, at 12.45 for 1.15 P.M. Members and their guests are requested to use the *Ballroom* entrance.

The Official Business to be transacted at the opening meeting will include a resolution to amend certain Bye-Laws, formal notice of which was given at the Autumn General Meeting in 1948 (*see* page 187 of the March, 1949, issue of the *Journal*).

The morning session on Thursday, 28th May, should be of special interest to members of the Iron and Steel Engineers Group.

The following is a tentative programme :

Wednesday, 27th April, 1949

9.45 a.m. to 1.30 p.m.—Morning Session, Lecture Theatre, Central Hall, Westminster

9.45 A.M. to 10.30 A.M.—
Official Business
Election of Members
Presentation of Report of Council, and Statement of Accounts for 1948
Resolution to Amend Bye-Laws Nos. 3, 21, 35, and 36
Presentation of the Bessemer Gold Medal for 1949
Presentation of the Sir Robert Hadfield Medal for 1949
Presentation of the Williams Prize for 1948
Presentation of the Ablett Prize for 1948.

10.30 A.M. to 11.30 A.M.—Discussion on :
" *The Conversion to Oil-Firing of the Open-Hearth Furnaces at Park Gate Works*," by D. F. Marshall and H. C. White (*April*, 1949)

11.30 A.M. to 12.30 P.M.—Discussion on :
" *An Electrical Pressure Meter for Measurement of Open-Hearth Furnace Differential Pressures*," by S. S. Carlisle and B. O. Smith (*March*, 1949)

12.30 P.M. to 1.15 P.M.—
Discussion (time permitting) on :
" *The Influence of Smoke and Atmospheric Absorption on Optical Pyrometry in Steelworks*," by J. A. Hall (*November*, 1948)

1.15 P.M. to 2.30 P.M.—Buffet Luncheon in the Library of the Central Hall, Westminster (tickets, price 6*s.* each, will be available at the Central Hall).

2.30 p.m. to 5.0 p.m.—Afternoon Session, Lecture Theatre, Central Hall, Westminster

2.30 P.M. to 3.30 P.M.—Discussion on :
" *The Thermodynamics of Substances of Interest in Iron and Steel Making from 0° C. to 2400° C. I—Oxides*," by F. D. Richardson and J. H. E. Jeffes (*November*, 1948)

3.30 P.M. to 4.30 P.M.—Joint Discussion on :
" *Large Crystal Grain Size in Silicon-Chromium Valve Steel*," by C. C. Hodgson and H. G. Baron (*February*, 1949)
" *Grain Growth in Silicon-Chromium Valve Steel*," by H. Allsop and P. W. Bygate (*April*, 1949)

4.30 P.M. to 5.0 P.M.—Discussion (time permitting) on :
" *The Structure of Carbides in Alloy Steels*," by H. J. Goldschmidt (*December*, 1948).

Thursday, 28th April

9.45 a.m. to 12.15 p.m.—Morning Session, The Institution of Mechanical Engineers, Storey's Gate

9.45 A.M. to 10.45 A.M.—Joint Discussion on :
" *The Charging of Open-Hearth Furnaces by Present Methods*," by E. L. Diamond and A. L. Frankau (*March*, 1949)
" *The Influence of Heat-Transfer on Open-Hearth Furnace Charging Rate*," by M. W. Thring (*March*, 1949)

10.45 A.M. to 11.45 A.M.—Discussion on :
" *The Layout of Integrated Steelworks in Great Britain*," by H. H. Mardon and J. S. Terrington (*April*, 1949)

11.45 A.M. to 12.15 P.M.—Discussion (time permitting) on :
" *The Application of Dry Coke Cooling Plants to Integrated Iron and Steel Works*," by L. H. W. Savage and A. V. Brancker (*February*, 1949)

12.45 P.M. for 1.15 P.M.—Members Luncheon at the Dorchester Hotel, Park Lane, W.1.

Note—The issues of the *Journal* in which the papers appear are given in brackets.

Special Summer Meeting in Norway, 1949

Particulars and programme of the Special Summer Meeting to be held in Norway, from 28th May to 7th June, 1949, were given in the February *Journal*, pp. 139–140.

Jernkontorets Annaler

From the beginning of 1949 the annual subscription for *Jernkontorets Annaler* has been increased to 20 Swedish kroner. Under the arrangement for collaboration between Jernkontoret and The Iron and Steel Institute, the subscription rate to Members of the Institute will be at the reduced rate of 15 Swedish kroner. Members wishing to avail themselves of this reduction should inform Jernkontoret that they are Members of the Institute when ordering *Jernkontorets Annaler*.

NEWS OF MEMBERS

▶ Mr. VERNON HARBORD has been elected a Vice-President of the Institution of Mining and Metallurgy for 1949–50.

▶ Mr. R. E. COCKADAY, student in the Metallurgical Department, Leeds University, has been appointed Scientific Officer, Ministry of Supply, Chemical Inspectorate, Springfields, Salwick, near Preston.

▶ Mr. G. H. BLACK has been appointed a director of Messrs. Kestner Evaporator and Engineering Co., Ltd.

▶ Mr. J. Y. HIGGS has been awarded the degree of B.Sc. (Eng.) (Hons. Met.) of London University.

▶ Mr. A. J. K. HONEYMAN has been appointed chief metallurgist, Steel Division, Steel Company of Wales, Ltd., as from 1st February.

▶ Mr. M. M. MISRA has completed his training in foundry practice and metallurgy, and has taken a position in the Indian Iron and Steel Company's foundry, West Bengal.

▶ Dr. E. C. ROLLASON has been elected Chairman of the editorial committee of the Institute of Welding, and British delegate on the Commission on Weldability of the International Institute of Welding.

▶ Mr. JOHN P. SUTCLIFFE has recently taken up the appointment of production superintendent at the Noranda Copper and Brass, Ltd., Montreal East, Canada.

▶ Mr. J. W. TAYLOR has been awarded the degrees of B.Sc. (Hons. Met.) Glasgow, and A.R.T.C., Glasgow.

▶ Mr. F. T. L. DAVIES is now chief metallurgist with British Acoustic Films, Ltd., Mitcheldean, Glos.

▶ Mr. B. ELLIOTT of Messrs. Higher Speed Metals, Ltd., Sheffield, has resigned from the Board of Messrs. Tool and Steel Products, Ltd., and has acquired the businesses of Messrs. Alteg Metals, Ltd., and Messrs. Mackereth and Co., Ltd., which have now been merged.

▶ Mr. W. G. GLAISHER is now at the Experimental Station of the Steelmaking Division of the British Iron and Steel Research Association, at 41 Doncaster Street, Sheffield.

▶ Mr. M. K. HALDAR has resigned the post of research officer at the Textile Machinery Corporation, Ltd., Belghurriah, West Bengal, and has joined the Fuel Research Institute, Dhanbad, India, of the Council of Scientific and Industrial Research, under the Ministry of Research, Government of India, as junior scientific officer.

▶ Dr. J. E. HURST, of Lichfield, has been appointed Managing Director of Messrs. Bradley and Foster, Ltd., Bradleys (Concrete) Ltd., Bradleys (Darlaston) Ltd.; and Chairman and Managing Director of Arblaster and Co., Ltd., and Ernest Graham and Co., Ltd., in place of Mr. G. T. Lunt (deceased). Dr. Hurst will continue to hold the offices of Director of Research, Staveley Coal and Iron Co., Ltd., and Technical Director of the Birmingham Chemical Co., Ltd.

▶ Monsieur J. DURAND, Ingénieur en Chef, Cie des Forges et Aciéries de la Marine et d'Homecourt, has been nominated Officier de la Légion d'Honneur.

▶ Mr. P. A. JOB has been awarded the M.B.E. in the New Year Honours.

▶ Monsieur DAMIEN, Directeur-Général of the Société Denain-Anzin, has been nominated Officier de la Légion d'Honneur.

▶ Professeur P. BASTIEN, Directeur Scientifique, Sté Schneider et Cie., has been nominated Chevalier de la Légion d'Honneur.

▶ Mr. P. E. KERSTING has been elected an Associate of the Institution of Metallurgists, and is now a metallurgist at Messrs. Stewarts and Lloyds, Ltd., Corby.

▶ Mr. A. T. GREEN, Director of the British Ceramic Research Association, has been awarded the honorary degree of D.Sc., Leeds University.

▶ Mr. G. E. LUNT, Tettenhall, Wolverhampton (son of the late Mr. G. T. Lunt, Managing Director) has been appointed a Director of Messrs. Arblaster and Co., Ltd., and Ernest Graham and Co., Ltd.

▶ Mr. DOUGLAS JEPSON has left the Metallurgical Department, Manchester University, to join the Research Department, Messrs. Hadfields, Ltd., Sheffield.

▶ Mr. W. J. KLIMECKI has left the Royal College of Science, London, and is now working in the Physics Department, The Instytut Metalurgii, Gliwice, Poland.

▶ Mr. MAURICE J. OLNEY has resigned the position of metallurgist, British Thermostat Co., Ltd., Sunbury-on-Thames, and is now engaged in research work in the Department of Metallurgy, University of Cambridge.

▶ Mr. J. ARTHUR REAVELL, Chairman of Kestner Evaporator and Engineering Co., Ltd., is visiting South Africa early this year.

▶ Mr. D. V. REDDI has been elected an Associate of the Royal Institute of Chemistry of Great Britain and Ireland.

▶ Mr. A. ROEBUCK has been elected President of the Sheffield Metallurgical Association, and becomes an Hon. Member of Council of the Institute.

▶ Mr. T. W. RUFFLE has left the Motor Industry Research Association, to take up the position of chief metallurgist, E.N.V. Engineering Co., Ltd., Willesden, N.W.10.

▶ Mr. R. TOYE, research physicist, B.I.S.R.A., Swansea, is now at the Steelmaking Division, B.I.S.R.A., 41, Doncaster Street, Sheffield, 3.

▶ Mr. F. M. THOMAS has left the Appleby Frodingham Steel Co., Ltd., Scunthorpe, to become assistant metallurgist in the Research Department of Needle Industries, Ltd., Studley, Warwickshire.

▶ Mr. F. USHER-SMITH, and Mr. R. M. HYSLOP have been appointed Managing Directors of Messrs. Bayliss, Jones and Bayliss, Ltd., Wolverhampton, as from 1st January, 1949, in place of Mr. P. S. Bayliss and Mr. F. W. Bayliss, retired.

▶ Mr. L. H. WALKER has resigned from Reynolds Rolling Mills, Ltd., Oldbury, to spend a year in the U.S.A. and Canada on light alloy manufacture and research, under a 1947 Mond Nickel Fellowship.

▶ Mr. SIDNEY WORNE has severed his connection with the Wellman Smith Engineering Corporation, Ltd.

▶ Mr. C. T. WILSHAW has been appointed metallurgist to the Bahrein Petroleum Co., Ltd., Bahrein Island, Persian Gulf.

▶ Mr. GULSHER MOHAMMAD KHAN has been appointed control officer, Surgical Instruments and Allied Trades Development Centre, Sialkot, West Punjab, Pakistan.

▶ Mr. N. Y. NEWTON has been transferred from the Sheffield branch of the English Steel Corporation, Ltd., to their Openshaw branch.

▶ Mr. E. G. BAYLISS has left Messrs. Forgings and Presswork, Ltd., and is now chief metallurgist, Messrs. John Garrington and Sons, Ltd., Bromsgrove, Worcester.

▶ Dr. F. A. FOX has relinquished his appointment as Deputy Director, British Welding Research Association, and is now deputy technical manager, Messrs. H. J. Enthoven and Sons, Ltd., London, E.C.3.

▶ Mr. N. H. ROLLASON has been re-elected President-Elect, British Iron and Steel Federation.

▶ Mr. G. S. SHAW has left Leeds University to become a student of metallurgy, Birmingham University.

▶ Dr. S. T. JAZNINSKI has resigned the positions of chief metallurgist, Barium Steel Corporation, vice-president and director of Sheffield Iron and Steel Co., and vice-president, Detroit Steel Casting Co., and has taken the position of technical director, Cia Ferro e Aco de Vitoria, South America.

▶ Mr. H. R. HEAP has been appointed metallurgist, English Electric Co., Ltd., Nelson Research Laboratories, Stafford.

▶ Mr. H. G. BARON has left Messrs. Leyland Motors, Ltd., to become a student at Manchester University.

▶ Mr. P. G. CLEMENTS has resigned the position of development chemist, Schori Metallising Process, Ltd., to join Messrs. Joseph Crosfield and Sons, Ltd., Warrington.

▶ Mr. M. B. SANDERS has been appointed laboratory technician, Department of Metallurgy and Fuel Technology, University College, Cardiff.

▶ Mr. D. WORTH has become a student of metallurgy, Leeds University.

Obituary

Mr. GEORGE TALBOT LUNT, Managing Director, Messrs. Bradley and Foster, Ltd., on 4th January, 1949, aged 60.

Mr. THEODORE W. ROBINSON, Chairman of the Board of the Illinois Steel Co., Incorporated, Illinois, U.S.A., on 30th December, 1948.

Mr. WALTER DORRINGTON, Director, E. C. and J. Keay, Ltd., Birmingham, aged 81.

Monsieur FRANÇOIS DE WENDEL, President of the Comité des Forges, Paris, on 12th January, aged 74.

Mr. BERNARD W. METHLEY, consultant to the Research and Development Department of the United Steel Companies, Ltd., at Rotherham on 14th January, aged 72.

Mr. CYRIL WALTON, on 23rd December, 1948.

CONTRIBUTORS TO THE JOURNAL

Carl A. F. Benedicks, Fil.Dr. of the Benedicks Laboratory, Stockholm.—Dr. Benedicks, whose biography appeared in the November, 1948 issue of the *Journal*, has, since 1945, discovered two cohesive effects: the "wetting effect," substantially affecting the tensile strength of solids; and the "liquo-striction effect," a reversible expansion of a solid when wetted.

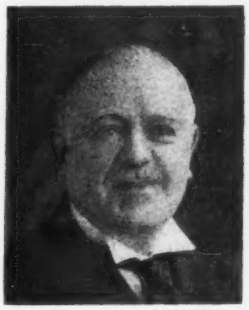
J. A. Sanderson, M.I.Mech.E.—Senior executive of Davy and United Engineering Co., Ltd., Sheffield. Mr. Sanderson was born in Sheffield in 1880, attended the Springfield School, the Central High School, and Sheffield Technical School. He served his apprenticeship with Davy Brothers Ltd., Park Iron Works, Sheffield, and was sales engineer and manager from 1914–34. In later years Mr. Sanderson was responsible for the negotiation and supervision of important foreign contracts for Russia, Poland, Italy, Spain, and other countries, for heavy forging presses and railway wheel, tyre, and axle forging plant. At the present time Mr. Sanderson acts as technical adviser and consultant to the company.

Olof Arvid Axelsson Tenow, Fil.Lic.—In charge of the Laboratory, Messrs. C. Benedicks, Stockholm. Mr. Tenow was born at Domnarvet, Sweden, in 1876. He was educated at the Gymnasium, Vesteras, and the University, Upsala, where he received the degree of Fil.Lic. in 1904. He was assistant in physical chemistry at the University of Basel, 1904–05, and acted in place of Professor G. Kahlbaum (decd.) in 1905–06. From 1911–21 he was amanuensis at the Physical Institute of the University of Stockholm; from 1921–22 he was consultant at the Metalografiska Institutet. In 1932 he was study-travelling in England, France and Germany. He worked in industry in America from 1925–33, and in Germany from 1933–36. From 1939–44 he was assistant in the laboratories of Messrs. G. Ising. He took up his present position with Messrs. C. Benedicks in 1946.

A. M. Frankau, M.A.—Assistant mechanical engineer in the Plant Engineering Division of B.I.S.R.A. Mr. Frankau was born in 1921, and was educated at Rugby School and Cambridge University. In 1941 he gained honours in the Mechanical Sciences Tripos. He served five years with the Royal Air Force as a specialist signals officer on radar in Britain and India, and attained the rank of Squadron Leader. In 1946 he returned to Cambridge University, and took honours in Metallurgy in Part II of the Natural Sciences Tripos. He took up his present position in October, 1947.

J. G. Frith, A.M.I.Mech.E.—Assistant chief engineer in charge of hydraulic machinery, at Davy and United Engineering Co., Ltd., Sheffield. Mr. Frith served his apprenticeship in the shops and drawing office of Messrs. Davy and United Engineering Co., Ltd., and has remained with that firm. He recently visited the United States of America to study American hydraulic practice.

S. S. Carlisle, M.Sc., A.M.I.E.E.—In charge of the Instrument Section of the Physics Department of the British Iron and Steel Research Association. Mr. Carlisle graduated at Queens University, Belfast (College of Technology), in electrical engineering, and later continued his studies at the College, being granted the degree of M.Sc. in 1942. During his course of higher study he was appointed a temporary lecturer in radio and radio-physics at the College. In 1942 he joined the staff of the Director of Scientific Research, Admiralty, and was stationed for four years on H.M.S. *Excellent*, Portsmouth, where he was engaged on the development and trials of radar and gun control equipment, being particularly concerned with the development of electrical predictors. In 1946 he joined the staff of B.I.S.R.A., and in 1947 was appointed Head of the Instrument Section.



J. A. Sanderson

O. A. A. Tenow

J. G. Frith

S. S. Carlisle

B. O. Smith

A. M. Frankau

B. O. Smith, B.Sc.—Research physicist, British Iron and Steel Research Association, Battersea. Mr. Smith was born in 1921. He was educated at Hampton Grammar School, and King's College, London, and gained the Degree of B.Sc., in physics in 1941. From 1941–46 he served in the Technical Branch of the R.A.F. as a radar officer. He took up his present position in 1946.

IRON AND STEEL ENGINEERS GROUP

The Ninth Meeting of the Iron and Steel Engineers Group will be held at the offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, on Wednesday, 23rd March, 1949, commencing at 10.30 A.M.

Three papers are to be presented and discussed :

"*A Review of the Application and Design of Heavy Forging Presses*," by J. A. Sanderson and J. G. Frith (Davy and United Engineering Co., Ltd.) (published in the March, 1949, issue of the *Journal*).

"*Heavy Forging Manipulators*," by A. V. Flinn (Adamson-Alliance Co., Ltd.). (This paper will be presented at the meeting and published later.)

"*A Modern Heavy Forging Plant*," by W. H. Alvey (English Steel Corporation, Ltd.) (published in the February, 1949, issue of the *Journal*).

A Buffet Luncheon will be held in the Joint Library in connection with the meeting.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Associate Membership

Of importance to all firms and individuals interested in the manufacture and use of iron and steel, but not themselves makers or processors, is the announcement that the British Iron and Steel Research Association will now admit them to a newly established category of Associate Membership.

B.I.S.R.A.'s activities since its formation in 1945 have largely concerned the making and shaping and the properties of iron and steel, and have clearly shown how researches of this nature relate closely at one end with the industry's suppliers of raw materials and capital equipment, and at the other with the users of its products. Co-operation at each end has been close as, for example, in work on the design of new plant which has involved suppliers, and in work on a wide variety of corrosion problems which has involved users to a considerable extent.

The present step, therefore, carries this co-operation a stage further, and gives firms and individuals of allied or interested industries a more direct opportunity of influencing the Association's research programme (at present numbering some 400 projects), and of having access to research results at the earliest possible moment. For example, Associate Members will receive research reports and will be able to attend the technical conferences which are a feature of B.I.S.R.A.'s information methods, numbering about twenty yearly and covering almost every aspect of the Association's work.

The organization of B.I.S.R.A. into six largely autonomous divisions, enables Associate Members to restrict their participation to selected fields, if they wish. Trade Associations are not eligible, and in the fields of coke and refractories such close collaboration between B.I.S.R.A. and the respective Research Associations already exists, with full exchange of information, that membership by firms in those industries would serve little practical purpose.

Associate Members will be drawn, it is expected, from a wide range of other industries, providing another link in the essential bond between industry and science.

INSTITUTE OF METALS

Annual General Meeting in London, 1949

The Annual General Meeting of the Institute of Metals will be held in London, on Wednesday and Thursday, 30th and 31st March, at The Institution of Mechanical Engineers, Storey's Gate, S.W.1, and on Friday, 1st April, at 4 Grosvenor Gardens, S.W.1. An outline of the programme is as follows :

Wednesday, 30th March, 1949

10 A.M. General Meeting—Annual Reports ; election of officers for 1949–50 ; presentation of the Institute of Metals (Platinum) Medal for 1949.

Discussion of papers :

(1) A. P. C. HALLOWES : "The Working Behaviour of Phosphorus-Deoxidized Coppers Containing Bismuth." (*J. Inst. Metals*, September, 1948).

(2) K. M. ENTWHISTLE : "The Damping Capacity of Metals in Transverse Vibration." (*J. Inst. Metals*, October, 1948).

(3) K. M. ENTWHISTLE : "The Effect of Grain-Size on the Damping Capacity of Alpha Brass." (*J. Inst. Metals*, October, 1948).

1.5 P.M. Buffet Lunch.

2.30 P.M. Discussion of papers :

(1) C. BLAZEY, L. BROAD, W. S. GUMMER, and D. B. THOMPSON : "The Flow of Metal in Tube Extrusion." (*J. Inst. Metals*, December, 1948).

(2) T. HOWARD ROGERS : "The Promotion and Acceleration of Metallic Corrosion by Micro-Organisms." (*J. Inst. Metals*, September, 1948).

Thursday, 31st March

10 A.M. General discussion on a symposium of six papers on "Non-ferrous Metal Melting and Casting of Ingots for Welding," published in the Journal of the Institute of Metals, January, 1949.

1.5 P.M. Buffet Lunch.

2.30 P.M. Discussion resumed.

7.15 P.M. Dinner-Dance at the Savoy Hotel, Strand, W.C.2.

Friday, 1st April

10 A.M. A discussion on the following papers :

(1) P. C. VARLEY : "The Recovery and Recrystallization of Rolled Aluminium of Commercial Purity." (*J. Inst. Metals*, December, 1948).

(2) W. I. PUMPHREY and P. H. JENNINGS : "High-Temperature Tensile Properties of Cast Aluminium–Silicon Alloys and their Constitutional Significance." (*J. Inst. Metals*, December, 1948).

(3) W. I. PUMPHREY and P. H. JENNINGS: "A Consideration of the Nature of Brittleness at Temperatures Above the Solidus in Castings and Welds in Aluminium Alloys." (*J. Inst. Metals*, December, 1948).

(4) W. I. PUMPHREY and D. C. MOORE: "A Consideration of the Nature of Brittleness at Temperatures Below the Solidus in Castings and Welds in Aluminium Alloys." (*J. Inst. Metals*, December, 1948).

(5) H. BURDEN and A. BARKER: "The Measurement of Grain-Size of Tungsten and Tungsten Carbide Powders Used for the Manufacture of Hard Metal." (*J. Inst. Metals*, October, 1948).

1 P.M. The General Meeting will conclude.

Visitors will be welcome at all sessions of the General Meeting.

NEWS OF SCIENCE AND INDUSTRY

Fourth Empire Mining and Metallurgical Congress

Members are reminded that replies to the Second Circular, giving particulars of the choice of excursion centres, accommodation, etc., should be submitted to the Organizing Secretary by 1st March, 1949.

Conference on Combined Heat and Power Supplies

The Institute of Fuel has arranged two conferences on Combined Heat and Power Supplies. The first Conference was held on 25th January, 1949, and the second will take place on 27th April, in the Lecture Hall of the Institution of Mechanical Engineers, Storey's Gate, S.W.1. The sessions, at 10 A.M. and 2 P.M., are open to all members of The Iron and Steel Institute, who are invited to take part in the discussion.

First National Exhibition of Industrial Finishing

The conception of the first National exhibition of industrial finishing, to be held from 31st August to 13th September, 1949, at Earls Court, London, S.W., arose from investigations by the Council of Industrial Design on the interrelation of finish, design, service conditions, and cost, as they affect consumer goods and machinery. A Central Technical Exhibit will graphically present unbiased and authoritative information on industrial finishes. Enquiries should be addressed to the Exhibition Secretary, 1949 Industrial Finishes Exhibition, 26 Old Brompton Road, S.W.7.

World Power Conference

The Fourth World Power Conference will be held in London from 10th–15th July, 1950. The headquarters of the Conference will be The Institution of Civil Engineers, Great George St., S.W.1. The following appointments have been accepted: Sir Harold Hartley, K.C.V.O., C.B.E., F.R.S., Chairman of the Conference and of the Organizing Committee; Mr. Harold Hobson, formerly Chairman of the Central Electricity Board, Chairman of the Programme and Papers Committee; Mr. D. W. Coates, Chief Accountant of the British Electricity Authority, Chairman of the Finance Committee; Colonel C. M. Croft, D.L., J.P., of the Wandsworth and District Gas Co., Chairman of the Reception and Entertainments Committee; Mr. C. H. Gray, Secretary of the International Executive Council of the World Power Conference, General Secretary.

The technical programme, obtainable from The General Secretary, Fourth World Power Conference, 201–2, Grand Buildings, Trafalgar Square, London, W.C.2, includes: (*i*) single reports on energy resources and historical records of development from each National Committee of the World Power Conference; (ii) papers dealing with fuel preparation; (iii) papers on production of power, including gas turbines, jet engines, hot-air engines, tidal power, wind power, solar energy, terrestrial heat, thermal energy derived from the sea, and atomic energy.

Capper Pass Awards

The adjudicating committee of the Capper Pass Awards, particulars of which were published in the *Journal* for April, 1948 (News Section) will shortly consider for awards, all papers published by the Institution of Mining and Metallurgy, and the Institute of Metals, during 1948. The awards will be published in the respective journals and in the Press.

Nuffield Foundation Research Fellowship in Extraction Metallurgy

The date for the receipt of applications for the Nuffield Foundation Research Fellowship in Extraction Metallurgy has been put forward to 31st March, 1949. The Fellowship will be tenable at the Royal School of Mines, London, for a period of up to five years, and the funds available are sufficient to provide a salary of from £1,200 to £1,500 a year, for the Fellow, and some £2,500 a year for assistants and apparatus.

Applicants should have had experience in the initiation and development of research, preferably in industrial research establishments. No conditions are laid down regarding the nature of the research, provided that it is concerned with extraction metallurgy, but preference will be given to a candidate who proposes to study some problems bearing on the basic scientific principles of metal extraction. Applications, giving details of the candidate's qualifications and experience, the names of three referees, and an outline programme of research, should be sent to the Secretary, the Institution of Mining and Metallurgy, Salisbury House, London, E.C.2.

American Broaching Machines

The Coventry Gauge and Tool Co., Ltd., Coventry, and the Rockwell Machine Tool Co., Ltd., Wembley, have concluded an agreement with the American Broach and Machine Co., Michigan, U.S.A., for the manufacture of American broaching machines in Britain. The machines will be sold and serviced by the Rockwell Machine Tool Co., Ltd.

Cutanit, Ltd.

As from 1st January, 1949, Messrs. Cutanit and Metropolitan-Vickers have proprietary interests in a new company, called Metro-Cutanit, Ltd. This company has been formed to acquire the businesses of Messrs. Cutanit and of Compound Electro Metals, Ltd., and the manufacturing plant at present operated at Allen Street, Warrington by Metropolitan-Vickers Electrical Co., Ltd.

Blast-furnace Renewal Contracts

The No. 1 furnace of the Cargo Fleet Iron Co., Ltd., is to be modernized by Messrs. Ashmore, Benson, Pease and Co., Ltd., who are also supplying equipment for a furnace designed by the Freyn Engineering Co., for the Polish Government.

Memoranda

The Public Relations department of the Manchester Oil Refinery group of companies, Petrocarbon, Ltd., and Petrochemicals, Ltd., have their offices now at 44A Dover Street, London, W.1.

Mr. W. A. C. NEWMAN, Honorary Treasurer, Institute of Metals, has been elected President of the Institution of Mining and Metallurgy for 1949–50.

Mr. SIMON NEVILLE TURNER, Deputy Managing Director of the Staveley Coal and Iron Co., Ltd., has been appointed a Director of Messrs. Bradley and Foster, Ltd., Bradleys (Concrete) Ltd., and Bradleys (Darlaston) Ltd.

Mr. C. H. WILLIAMS, chief engineer of the Carnegie-Illinois Steel Corporation, has been elected President of the American Association of Iron and Steel Engineers.

Mr. GEORGE ARCHER, C.M.G., and Mr. L. K. BRINDLEY, M.B.E., were appointed Directors of the Mond Nickel Co., Ltd., on 1st December, 1948.

Siemens-Schukert (Great Britain) Ltd.

The whole of the share capital of Messrs. Siemens-Schuckert (Great Britain) Limited, has been acquired from the Custodian of Enemy Property by Messrs. Bryce, Ltd., of Kelvin Works, Hackbridge, an Associated Company of The Hackbridge Cable Co., Ltd. The new proprietors state that the present policy in connection with the sales and technical developments of the range of products now manufactured by the Company will continue.

Woodall-Duckham Vertical Retort and Oven Construction Co., Ltd.

Mr. F. P. DYSON, Chief Engineer of the construction department, Mr. H. KERR, chief engineer, gas and coking industries plant, and Mr. A. F. TOPLEY head of the sales department, have been appointed directors of the Woodall-Duckham Vertical Retort and Oven Construction Co., Ltd., as from 1st January, 1949.

DIARY

14th Mar.—INSTITUTE OF BRITISH FOUNDRYMEN (Sheffield Branch)—"*Refractory Materials in the Foundry Industry*," by A. T. Green and G. R. Rigby—Royal Victoria Station Hotel, Sheffield, 7.30 P.M.

16th Mar.—INSTITUTE OF WELDING (West of Scotland Branch)—"*The Application of Welding for High Pressure and High Temperature Equipment*," by H. Harris and J. Jones—39, Elmbank Crescent, Glasgow, 7.0 P.M.

18th Mar.—WEST OF SCOTLAND IRON AND STEEL INSTITUTE—"*Factors Affecting the Quality of Pig Iron*," by R. P. Towndrow—39 Elmbank Crescent, Glasgow, 6.45 P.M.

19th Mar.—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—"*The Utilisation of Steam*," by Oliver Lyle—Lecture Room, Central Library, Swansea, 6.30 P.M.

21st Mar.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—"*Some Recent Advances in the Study of Refractory Materials*," by A. T. Green.—Royal Victoria Station Hotel, Sheffield, 6.15 P.M.

24th Mar.—MIDLAND METALLURGICAL SOCIETIES—Exhibition of sound films: "*Steelmaking*," and "*Mitia*"—James Watt Institute, Birmingham, 6.30 P.M.

25th Mar.—INSTITUTE OF METALS (Sheffield Local Section)—Annual General Meeting: Exhibition of films—Grand Hotel, Sheffield, 6.30 P.M.

30th Mar.–1st Apr.—THE INSTITUTE OF METALS—Annual General Meeting—The Institution of Mechanical Engineers, Storey's Gate, London, S.W.1, on 30th and 31st March, and at 4 Grosvenor Gardens, London, S.W.1, on 1st April, 10 A.M.–5 P.M.

4th Apr.—INSTITUTE OF BRITISH FOUNDRYMEN (Sheffield Branch)—Annual Meeting. "*The Feeding of Steel Castings*," by B. Gray—Royal Victoria Station Hotel, Sheffield, 7.30 P.M.

5th Apr.—PHYSICAL SOCIETY—33rd Exhibition—Annual exhibition of scientific instruments and apparatus—Physics Department, Imperial College of Science and Technology, South Kensington.

7th Apr.—INSTITUTE OF METALS (London Local Section)—Annual General Meeting, 6.0 P.M. Open discussion on "*Controlled Atmospheres*," introduced by I. Jenkins, 7.0 P.M.—4 Grosvenor Gardens, London, S.W.1.

7th Apr.—LEEDS METALLURGICAL SOCIETY—Film on rocket-flight development—Chemistry Department, Leeds University, 7.0 P.M.

7th Apr.—INSTITUTE OF METALS (Birmingham Local Section)—Annual General Meeting—James Watt Memorial Institute, Great Charles Street, Birmingham, 6.30 P.M.

7th Apr.—THE INSTITUTE OF PHYSICS (Midland Branch)—"*Physics in Steel Manufacture*"—Imperial Hotel, Birmingham, 6.30 P.M.

9th Apr.—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—Film of the Ebbw Vale plant of Messrs. Richard Thomas and Baldwins, Ltd.; introduced by P. M. Macnair—Lecture Room, Central Library, Alexandra Road, Swansea, 6.30 P.M.

TRANSLATION SERVICE

(The previous announcement was made in the February, 1949, issue of the *Journal*, p. 144.)

TRANSLATIONS AVAILABLE

No. 373 (French). M. BRUN: "Factors Affecting the Coke Consumption in the Blast-Furnace in the Briey Region." (*Revue de Métallurgie, Mémoires*, 1945, vol. 42, Sept., pp. 273–285; Oct., pp. 308–320; Nov., pp. 347–358; Dec., pp. 393–401.) (Translation made available through the courtesy of Messrs. Richard Thomas and Baldwins, Ltd.)

No. 374 (German). P. KLINGER and W. KOCH: "Progress in the Isolation of Inclusions and Structural Constituents in Alloy and Unalloyed Steels." (*Stahl und Eisen*, 1948, vol. 68, Sept. 9, pp. 321–333.)

PAPERS ACCEPTED FOR TRANSLATION SINCE THE LAST ANNOUNCEMENT

(Italian). G. MALQUORI and V. CIRILLI: "Study of the Equilibrium of Reduction of Calcium Ferrites and Brownmillerite with Carbon Monoxide." (*Gazetta Chimica Italiana*, 1945, vol. 75, Aug./Sept., pp. 137–156.)

(Swedish). S. BERGH: "The Influence of Small Contents of Lead on the Hot-Workability of Austenitic Stainless Steels." (*Jernkontorets Annaler*, 1948, vol. 132, No. 6, pp. 213–220).

CHARGES FOR COPIES OF TRANSLATIONS—For the above translations a charge will be made of £1 for the first copy and 10*s.* for each additional copy of the same translation. Requests should be accompanied by a remittance. The above translations are not available on loan from the Joint Library.

TRANSLATIONS PREPARED AT MEMBERS' REQUEST—Members requiring translations of foreign papers are invited to communicate with the Secretary, who will ascertain whether the translations can be prepared for inclusion in the series.

ABSTRACTS OF CURRENT LITERATURE *and* BOOK NOTICES

IRON AND STEEL MANUFACTURE AND RELATED SUBJECTS

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MINERAL RESOURCES

The Coal Seams of Derbyshire, Nottinghamshire and Lincolnshire. A. Dawe and G. Coles. (Journal of the Institute of Fuel, 1948, vol. 22, Oct., pp. 12–19). There are several seams both above and below the Top Hard seam, which is the most widely worked in the Nottingham and Derbyshire coalfield; these can make good the deficiencies arising when output from this seam decreases; the deeper seams are suitable for coking and gas-making. The seams in Lincolnshire, though under 4000 ft. of cover, are of low rank and possess only moderate coking quality. The exterior of this field towards the borders of Leicestershire lies at a lesser depth and, though of low rank, it is likely to be developed sooner.—J. P. S.

Composition of Lorraine Iron Ores. Guinard. (Revue de l'Industrie Minérale, 1948, Oct., pp. 647–657). The work of previous investigators is reviewed, and the methods used for the determination of each mineral likely to be present in the ore, are described. Tables show the mineralogical analysis of a number of Lorraine iron ores.—R. F. F.

On the Geochemistry of Swedish Iron Ores and Associated Rocks. S. Landergren. (Sveriges Geologiska Undersökning, 1948, Series C, No. 496). This report, which is in English, deals with the geochemistry of iron ores. Significant minor constituents in samples from pre-Cambrian iron ores of Sweden have been obtained by spectrochemical analyses, and the results are presented. Special attention is paid to the principles governing the distribution of major constituents in iron ores and in igneous rocks, and a theory for the formation of iron ores is advanced.—R. A. R.

Properties and Uses of Bakal Siderite Ores. L. M. Tsylev. (Bulletin de l'Académie des Sciences, U.R.S.S., Classe des Sciences Techniques, 1947, No. 4, pp. 399–407: [Abstract] Centre de Documentation Sidérurgique, Bulletin Analytique, 1948, vol. 5, May, p. 12). The author deals with the composition of the ore, and the composition, qualities and defects of the iron and slags obtained when the siderite is mixed with other ores. The best mixture is deduced.

The Geology and Mineral Resources of Tanganyika Territory. G. M. Stockley. (Bulletin of the Imperial Institute, 1947, vol. 45, No. 4, pp. 375–406). The mineral resources of Tanganyika Territory include eight coalfields, of which five are relatively small, and three promise to be extensive. The greatest drawback industrially is the general lack of coking coal, and only one field of coking coal has so far been proved. Situated thirty-five miles north of the Ruhuhu coalfield there are large deposits of titaniferous magnetite. R. A. R.

That Labrador Iron Ore. (Engineering and Mining Journal, 1948, vol. 149, Nov., pp. 88–92). Data on the iron ores of the Ungava Trough in Labrador and Quebec are presented and discussed. It is estimated that if 300 million tons were available for mining by open-cast methods the huge capital investment for transport facilities would be justified. Test drillings and trenching have proved that much more than this exists. The ore is a mixture of brown and blue ore; it is mainly hematite with limonite bands. Analyses show from 52% to 65% of iron.—R. A. R.

Iron Ore Reserves of the Mesabi Range. E. W. Davis. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 101–106). *See* Journ. I. and S.I., 1947, vol. 156, July, p. 435.

ORES—MINING AND TREATMENT

Factors in Screening Ores. D. D. Howat. (Iron and Coal Trades Review, 1948, vol. 157, Dec. 3, pp. 1237–1242; Dec. 10, pp. 1303–1305). The first part of this article deals with fundamental factors in screening iron ores and those affecting efficiency. Various types of screen and screening surface are considered and their fields of application discussed. The second part deals with screening wet and sticky ores, and the permeability of beds to the flow of gases. Brief reference is made to the significance of the behaviour of ores on crushing and screening in relation to methods of concentrating low-grade iron ores.—J. C. R.

Concentration of Oxide Manganese Ores from the Aguila District, Arizona. W. G. Sandell and D. T. Holmes. (United States Bureau of Mines, 1948, Aug., Report of Investigations 4330). Tests are reported on three representative lots of manganese ore from Arizona to determine their amenability to concentration. Tabling, flotation, and a heavy-medium process were applied and the ores were found to be amenable to concentration for the production of high-grade manganese sinters.—R. A. R.

Concentration of Richmond Hill Oxide Manganese Ore from Lead, Lawrence County, S. Dak. G. M. Potter and K. C. Dean. (United States Bureau of Mines, 1948, Aug., Report of Investigations 4331). Richmond Hill oxide manganese ore was concentrated by different processes and found to be amenable to concentration by gravity methods.—R. A. R.

Iron Production Increased 38·2%. R. R. Williams, jun. (Steel, 1948, vol. 123, Nov. 8, pp. 112, 115, 118, 136–140). Plant has been erected by the Colorado Fuel and Iron Corp. at Pueblo, Colorado, for the crushing, sintering, and blending of iron ores from two different sources. By this means a uniform product for the blast-furnace is obtained and it is claimed that the output of iron was raised by 32·8%, the

coke consumption reduced by 9·7%, and the consumption of limestone by 36·3% ; the iron was more uniform in composition, and the operation of the furnace much smoother.—J. P. S.

Mining and Preparation of Limestone. (Iron and Coal Trades Review, 1948, vol. 157, Nov. 19, pp. 1119–1122). An account is given of mining operations at Cults Lime Works near Cupar in Scotland, with particulars of the plant for breaking and crushing the limestone, and an illustrated description of the gas-fired, vertical shaft calcining kilns. J. C. R.

FUEL—PREPARATION, PROPERTIES, AND USES

Power, Fuel and Steam Balances for a Modern Steel Plant. A. D. Howry. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 432–435). *See* Journ. I. and S.I., 1947, vol. 157, Dec., p. 629.

Relation of the Power Load to the Steam and Fuel Balances. H. L. Halstead. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 435–442). *See* Journ. I. and S.I., 1947, vol. 157, Dec., p. 629.

The Thermal Drying of Fine Coal. O. R. Lyons and A. C. Richardson. (American Institute of Mining and Metallurgical Engineers, Technical Publication No. 2399 : Coal Technology, 1948, vol. 3, Aug.). A survey is presented of modern practice in the thermal drying of coal. Data were obtained from plant tests with screen, rotary continuous-pallet, flash, tray, and cascade types of drier, and it was evident that all types of drier could be operated with the same degree of effectiveness if they were used to dry the sizes of coal for which they were best suited. It is claimed that by using this data it is possible, when the percentage of surface moisture and screen-size analysis of the coal to be dried has been determined and the desired final surface-moisture percentage has been fixed, to determine fairly accurately : (1) The difficulty of the drying problem ; (2) the required drier inlet gas temperature and volume, and exhaust gas temperature and volume ; (3) the type of drier to use ; and (4) the size of drier required. J. C. R.

Briquetting of Coke Breeze. A. C. Bose and N. N. Das Gupta. (Journal of Scientific and Industrial Research, India, 1948, vol. 7, pp. 71–78 : Chemical Abstracts, 1948, vol. 42, Sept. 20, col. 7006). Methods for briquetting coke breeze (dust, below ⅜ in., produced by screening metallurgical coke) were studied by compressing it with organic binders. Such briquettes for use as domestic or industrial fuels, must be sufficiently hard to withstand weathering and rough handling, but must not be so hard as to cause ignition difficulties in the furnace. Binders which gave promising results included " Kiri " (the solid waste product from the manufacture of shellac), heated coal tar, and mixtures of coal tar and pitch. No further work has been done on the briquetting problems because boilers have been installed which are especially designed to burn low-grade coals or coke breeze directly.

Procedure for the Sorting of Lean Coals According to Their Caking Tendency. E. M. Taits, V. K. Letova, and Z. S. Tyabina. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1229–1232). [In Russian]. A method of testing lean coals, in which the swelling of briquetted samples is measured, is described. The close relation which is shown to exist between coking properties and the swelling index enables the sorting of a large range of coals to be carried out on the basis of the above test. Some examples of the application of the procedure are given.—S. K.

Determination of the Lateral Contraction of the Coke Mass in the Coking Process. L. I. Erkin. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1224–1229). [In Russian]. A device is described measuring the distance between the wall of a coke oven and the surface of the charge, whereby the lateral contraction of the latter can be determined during the coking process. Special care was taken in the design of the apparatus to ensure that its readings would not be affected by changes in its temperature. An account is then given of experiments carried out at two different coking plants using different coals and coking conditions, the data relevant to each plant being presented. It was found that at one plant a gap between the oven wall and the charge first made its appearance after 10–11 hr. ; this increased to a maximum value of about 3 mm., whilst the corresponding figures for the other plant were 7–9 hr., and 6–9 mm.—S. K.

Practical Experiences in the Coking of Dangerous Low-Ash Coals. D. T. Barritt. (Yearbook of the Coke Oven Managers' Association, 1948, pp. 151–162). *See* Journ. I. and S.I., 1947, vol. 157, Nov., p. 463.

Some Observations on Coke Oven Practice in Belgium. J. R. Marshall. (Yearbook of the Coke Oven Managers' Association, 1948, pp. 151–156). A brief description is given of coke-oven practice at the Seraing coke ovens of Soc. An. John Cockerill where there are two batteries, one of 64 Semat Solvay ovens working on rich gas, and the other of 44 Coppee underfired compound ovens working mainly with blast-furnace gas.—R. A. R.

Dry Quenching of Incandescent Coke in Coking Plants and Gasworks. W. Hersche. (Monats Bulletin, Schweizerischer Verein von Gas-und Wasserfachmännern, 1948, vol. 28, Feb., pp. 29–37 : [Abstract] Chimie et Industrie, 1948, vol. 60, Oct., p. 349).

Advantages of Using Coke-Oven Gas in Industrial Furnaces. A. Graff. (Revue Technique Luxembourgeoise, 1948, vol. 40, Oct.–Dec., pp. 183–194). The properties and applications of coke-oven gas for heating purposes are discussed, with special reference to the use of coke-oven gas in Luxemburg. R. F. F.

Fire Prevention and Safety in By-Products and Benzol Plants. R. W. Schirmer. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 412–416). *See* Journ. I. and S.I., 1947, vol. 157, Nov., p. 463.

TEMPERATURE MEASUREMENT AND CONTROL

Comparison of Systems for Controlling Gas-Fired Furnace Process Temperatures. H. E. McClatchey. (Petroleum Processing, 1948, vol. 3, Sept., pp. 878–880 : [Abstract] Metals Review, 1948, vol. 21, Oct., p. 28). Details are given of three methods for controlling process temperatures in a gas-fired furnace, and the advantages and limitations of each are discussed.

New Type of Portable Temperature Regulator for Electro-Furnaces. Y. S. Ginsburg. (Kotloturbostroyenie, 1947, No. 4, pp. 29–30 : [Abridged Translation] Engineers' Digest (London) 1948, vol. 9, Nov., p. 368). A new type of automatic temperature regulator is described. This regulator consists of a porcelain rod in a steel tube ; it uses the difference in elongation of the rod and tube to operate a solenoid by means of a spring. This solenoid operates a mercury switch placed in the main furnace circuit. A by-pass through a rheostat allows the furnace to be fed by current reduced by 50%, when the mercury switch is open.—R. F. F.

Measurement of Heating Rates in Reheating Furnaces. J. W. Percy. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 401–411). *See* Journ. I. and S.I. 1947, vol. 157, Dec., p. 631.

REFRACTORY MATERIALS

Dead-Burned Dolomite. (Iron and Steel, 1948, vol. 21, Oct., pp. 449–450). **New Dolomite Works.** (British Steelmaker, 1948, vol. 14, Oct., pp. 453–456). A description is given of the new Cadeby Works of the Steetley Co., Ltd. It is designed for a yearly production of 375,000 tons of dolomite refractories and 75,000 tons of ground dolomite, and the new quarry has an estimated life of fifty years. J. C. R.

Basic Refractories Being Produced in Plant of Latest Design. C. Longenecker. (Blast Furnace and Steel Plant, vol. 36, Nov., pp. 1343–1346). The treatment of base refractories made from magnesite, olivine, and chrome ores at the Baltimore, Md., plant of Harbison-Walker Refractories Co., is described. This plant includes batch mixers, presses both for chemically and naturally bonded refractories, tunnel kilns, and an extensive dust-collection system.—J. P. S.

Control Laboratory for Steelplant Refractories of the Ecole Supérieure de la Métallurgie et de l'Industrie des Mines at Nancy. Schneider. (Revue de l'Industrie Minérale, 1948, Nov., pp. 703–704). The purpose and equipment of the laboratory are described.—R. F. F.

The Problem of Crucibles for High-Frequency Furnaces. F. M. Bosch and H. Haemers. (Société Française de Métallurgie, Oct. 9, 1947 : Revue de Métallurgie, Mémoires, 1948, vol. 45, Sept., pp. 312–316). After touching on certain properties of acid and basic materials used for lining high-frequency steel furnaces and the danger of molten steel

penetrating magnesite linings and its prevention by the use of two-layer crucible walls, in which the inner surface is a hard frit, while the remainder is powdery, the authors give an account of their examination of several natural magnesites from the points of view of their behaviour when used to make crucibles, their tendency to fissuration, and their rate of fritting.—A. E. C.

Refractory Economy in Steel Mill Furnaces. E. N. Hower. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 369–373). *See* Journ. I. and S.I., 1947, vol. 157, Nov., p. 465.

Carbon Hearth Installations at Homestead. C. J. Fleisch. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 687–690). *See* Journ. I. and S.I., 1948, vol. 159, May, p. 85.

BLAST-FURNACE PLANT AND THE PRODUCTION OF PIG IRON

Experimental Furnaces of the British Iron and Steel Research Association. M. Davies. (Blast Furnace and Steel Plant, 1948, vol. 36, Nov., pp. 1332–1334). *See* Journ. I. and S.I., 1948, vol. 159, Aug., p. 434.

Blast-Furnace Plant. J. H. Ridsdale. (British Engineering Export Journal, 1948, vol. 31, Oct., pp. 614–621). Modern blast-furnace plant in Great Britain is described and illustrated so as to give an overall picture of the type of plant now being installed to meet current requirements.—R. A. R.

The Development of the Blast-Furnace Profile in Different Countries. P. Wolf. (Iron and Steel Institute, 1948, Translation Series, No. 364). This is an English translation of a paper which appeared in Stahl und Eisen, 1947, vol. 66–67, Dec. 4, pp. 411–416. (*See* Journ. I. and S.I., 1948, vol. 158, Mar., p. 395).—R. A. R.

The Rate of Driving Blast-Furnaces. K. Guthmann. (Iron and Steel Institute, 1948, Translation Series, No. 365). This is an English translation of a paper which appeared in Stahl und Eisen, 1947, vol. 66–67, Dec. 4, pp. 425–427. (*See* "Blast-Furnace Output per Unit Hearth Area," Journ. I. and S.I., 1948, vol. 158, Mar., p. 396).—R. A. R.

Automatic Regulation for Electric Ore-Melting Furnaces. Yu. E. Efroimovich. (Promyshlennaia Energetika, 1948, May, pp. 7–9 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 38). Circuit diagrams of the automatic regulator for electric ore-melting furnaces are presented. The theoretical bases and the computations of the relay coefficients are outlined.

Australian Iron and Steel. Part I. Centenary of the First Blast Furnace at Mittagong. J. D. Brown. **Part II. New Projects at Port Kembla, Whyalla and Elsewhere.** C. Lynch. (Iron and Steel, 1948, vol. 21, Nov. 18, pp. 504–506).

The Acceleration of the Analyses of Pig Iron in the Blast-Furnace. A. G. Bogdanchenko. (Zavodskaya Laboratoriya, 1948, vol. 14, Sept., pp. 1064–1069). [In Russian]. An account is given of experiments in which samples of pig iron taken at various stages of tapping, were analysed, the results showing that the composition of the metal remained virtually constant. The following method of sampling the pig iron was tested and found to be satisfactory: A ladle of molten iron taken from the runner when one-sixth of the charge has been tapped, is poured over a clean shovel to form a plate of metal 2–3 mm. thick, which, after cooling in water, is sent for analysis. Samples in the form of thin plates are easier to grind, and the analytical results can be received at the furnace by the end of tapping if the above procedure is followed, the accuracy of the results equalling that obtained by the usual sampling methods.—S. K.

Jacking Up a Blast Furnace Shell. J. Neary. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 524–527). *See* Journ. I. and S.I., 1948, vol. 158, Jan., p. 149.

Reducing Maintenance of Collector Assemblies. C. E. Baxter. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 557–560). *See* Journ. I. and S.I., 1948, vol. 158, Jan., p. 149.

Chemical Removal of Scale, Sludges and Oxides from Steel Plant Equipment. B. H. McDaniel. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 566–573). *See* Journ. I. and S.I., 1948, vol. 158, Jan., p. 149.

DIRECT PROCESSES

Making Iron Powder in the Tunnel Kiln. V. H. Gottschalk. (United States Bureau of Mines, 1948, Aug., Information Circular 7473). This circular gives information on German investigations of the final reduction of "DPG" iron powder in ceramic containers in a muffle tunnel kiln. The kiln, 164 ft. long, was indirectly fired with producer gas, and it was operated with 27 cars, each carrying 66 containers, 18 in. long, 8½ in. wide, and 8 in. high. Iron powders containing about 2% of carbon were self-reducing, whilst carbon-free powders required an addition of 3·3% of charcoal. Great difficulty was experienced in maintaining a protective atmosphere in the kiln and the measures taken, which included locks at each end of the kiln, are described. Data on the results obtained and costs are given.—R. A. R.

Laramie Sponge-Iron Pilot Plant. T. L. Johnston and W. M. Mahan. (United States Bureau of Mines, 1948, Sept., Report of Investigations 4376). The sponge-iron plant at Laramie, Wyoming, is described and tests are reported on iron ores from Wyoming, California, and Arizona. The iron ore is reduced to metal with coal or coke in an internally fired rotary kiln 81 ft. long with diameters of 9 ft. and 6 ft. for lengths of 32 ft. and 49 ft., respectively. Various methods of charging ore and coal were investigated. Iron pellets, nodules and briquettes were produced, and good steel was made in open-hearth and electric furnaces using this material in place of scrap.—R. A. R.

PRODUCTION OF STEEL

Progress in Wales: The Steel Company of Wales Project. (British Steelmaker, 1948, vol. 14, Sept., pp. 406–410). An illustrated description is given of the progress made in the erection of the new steel plant and rolling mill at Port Talbot for the Steel Company of Wales.—R. A. R.

Steel—India Steers Ahead. (Science and Engineering, 1948, vol. 1, Aug., pp. 21–23). It is shown that the present productive capacity of the steel industry of India is insufficient by 1 to 1·5 million tons/annum. It is planned to erect two new steel plants, one probably in North Bihar and the other in the Central Provinces, each with a capacity of 500,000 tons of ingots. Three consultants of international standing have been appointed.—R. A. R.

War Time Expansion of Carnegie-Illinois Steel Corporation in the Pittsburgh District. T. J. Ess. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 537–556). *See* Journ. I. and S.I., 1948, vol. 158, Jan., p. 150.

The Technical Trends in Steel Research. E. C. Bain. (Engineers' Club, St. Louis: Steel Processing, 1948, vol. 34, Aug., pp. 432–433, 439–441; Sept., pp. 477–478, 494). The part which research has played in the advancement of the iron and steel industry is discussed and illustrated by citing in chronological order a great many of the inventions and improvements which have taken place.—R. A. R.

Influencing the Nitrogen Content of Small-Converter Steel by Different Blowing Procedures. H. Jurich and W. Eilender. (Stahl und Eisen, 1948, vol. 68, Oct. 7, pp. 387–395). Tests, using an 1800-kg. side-blown converter with five tuyeres in a horizontal line for blowing cupola metal, to study methods of reducing the nitrogen content of the steel are reported. In general, the nitrogen content was less with side-blowing than with bottom-blowing. Increasing the fluidity of the slag did not lower the nitrogen content of the steel. Disregarding other influencing factors, the nitrogen content was reduced by (*a*) increasing the mean quantity of blast, (*b*) decreasing the blast pressure at the end of the blow, and (*c*) decreasing the blast pressure and blowing time. Adding ferrosilicon during the blow did not increase the nitrogen. The nitrogen content was independent of temperature. It is advantageous to begin blowing at a higher pressure, which should not be reduced too soon, and to reduce the pressure towards the end of the blow. The nitrogen content is increased by the deoxidation, and the ferrosilicon addition does not entirely account for this. After blowing, the oxygen content of the steel is higher with a thin slag than with a viscous slag, but this does not apply after deoxidizing.—R. A. R.

On the Question of the Effect of Converter Shape on the Nitrogen Content of Steel. T. Kootz. (Iron and Steel Institute, 1949, Translation Series, No. 368). This is an English translation of Confidential Report No. 72 (1944) of the Verein deutscher Eisenhüttenleute. It presents and discusses the results of tests on the relationship between converter-bath conditions and the nitrogen content of the steel produced. The converter capacity increased in a straight line with the

internal diameter, so that the depth of bath remained theoretically the same. In the larger converters the opportunity for nitrogen absorption from the rising air bubbles was therefore the same as in smaller ones. Variations in the nitrogen content of pig iron from the mixer caused equivalent variations in the nitrogen content at the drop in the flame, and letting the pig iron stand in the mixer for a long time reduced the nitrogen content of the iron and the finished steel. Increases in the contents of carbon, phosphorus, aluminium, and silicon decreased the nitrogen content of both pig iron and steel whereas increases in manganese, chromium, and vanadium increased it.—R. A. R.

Advantages of Bessemer Steel in Producing Tubular Products. E. G. Price. (Steel, 1948, vol. 123, Nov. 15, pp. 116, 119–120, 122, 124). The operation of the acid-Bessemer converter for producing steel for pipes is described. Steel for welded pipes is usually finished to a low carbon content and cast as rimmed or capped steel. For seamless tubes it is deoxidized at the end of the blow by the addition of molten iron to the converter and further deoxidized in the converter or in the ladle, by the addition of ferrosilicon and aluminium. The aluminium helps to fix the nitrogen, and titanium, zirconium, and boron may also be used for this purpose. Acid-deoxidized Bessemer steel is as good as, and in ultimate strength often better than, open-hearth steel, both at room and at elevated temperatures.—J. P. S.

Design of All-Basic Open Hearth. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 618–622). *See* Journ. I. and S.I., 1948, Jan., p. 150.

Relation of Heat Transfer to Successful Furnace Design and Operation. M. W. Thring. (Iron and Coal Trades Review, 1948, vol. 157, Nov. 12, pp. 1063–1071). Under most conditions, the hearth at the outgoing end of an open-hearth furnace receives most heat, confirming the idea that flames are too long. The author indicates that mixing can be improved and flames shortened either by increasing the gas velocity and giving it immediate access to a slow-moving air stream, using high-velocity air sharply blown into the gas stream as in the Venturi port, or using a modified Maerz port in which the gas jet passes through the centre of a 'curtain' of air flowing vertically upwards. An account is given of the development of instruments for measuring flame radiation and luminosity in furnaces and the use of models for studying luminosity, radiation, and combustion.

Speeding Open Hearth Charging. R. J. Harry. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 506–510). *See* Journ. I. and S.I., 1948, vol. 158, Jan., p. 151.

The Function of Open Hearth Instruments. G. R. Bashforth. (British Steelmaker, 1948, vol. 14, Sept., pp. 415–418); Oct., pp. 465–468). The most important phases of open-hearth furnace control in their probable order of merit are: (1) Combustion control; (2) furnace pressure control; (3) regenerator temperature and reversal control; and (4) roof temperature control. Instruments for these purposes are described, and the following instrumentation is recommended: (1) Combustion control by means of flow meters and an automatic fuel/air ratio regulator; (2) pressure control by the automatic regulation of the waste-heat-boiler fan speed; (3) thermocouples in the base of the regenerators or in the flues; (4) a water gauge for indicating the stack draft; and (5) an indicator of the temperature of the flue gases near the base of the stack. Automatic reversal and roof-temperature controls are not advocated.—R. A. R

Application of Models to Metallurgical Research. M. W. Thring. (Iron and Coal Trades Review, 1948, vol. 157, Nov. 5, pp. 1023–1025). This is an abridgement of a paper read before the Institution of Chemical Engineers. The author discusses the purpose of models and the processes which can be studied by the use of models. Particular reference is paid to the use of models to study reactions in the open-hearth furnace and the blast-furnace.

Flow Processes in the Hearth of Open-Hearth Furnaces. F. Kofler and G. Schefels. (Iron and Steel Institute, 1948, Translation Series, No. 366). This is an English translation of a paper which appeared in Stahl und Eisen, 1933, vol. 53, Feb. 10, pp. 162–167. (*See* Journ. I. and S.I., 1933, No. I, p. 501).

Tests on Oxygen Enrichment of Air Carried out at the Pompey Open-Hearth Steel Works. (Publications de l'Institut de Recherches de la Sidérurgie, July, 1948, Series A, No. 2). Tests were carried out, at the Pompey Steel Works, to determine the saving in fuel achieved by using oxygen-enriched air in a basic open-hearth furnace. An oil-fired open-hearth furnace of 47 metric tons capacity, with a charge of 70–75% scrap and liquid basic pig iron, was used for these tests. Results of tests are discussed and statistically tabulated. The need for further tests is emphasized.—R. F. F.

The Applications of Oxygen in Iron and Steel Metallurgy and Possible Future Developments. M. Grison. (Métallurgie, 1948, vol. 80, Nov., pp. 25–27, 29, 31). A review is given of the use of oxygen in the blast-furnace, the converter, and the open-hearth and electric furnaces.—J. C. R.

Basic Structural Design and Operating Conditions of Electric Ore-Melting Furnaces. S. S. Mikulinsky. (Promyshlennaia Energetika, 1948, Apr., pp. 1–3 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 38). Criteria for structural design and operating conditions of electrical melting furnaces and for the determination of optimum conditions are presented. Experimental results demonstrate the validity of computations.

Development of Electric Steel Furnaces in Switzerland. A. Oehler. (Schweizerische Bauzeitung, 1948, vol. 66, July 10, pp. 387–391: Electrical Engineering Abstracts, 1948, vol. 51, Dec., p. 318). This is a review of the development of electric furnaces for the treatment of steel, during the past sixty years, illustrated with photographs and diagrams.

Production of Electric Arc Furnace Steel. W. M. Farnsworth. (Steel, 1948, vol. 123, Dec. 20, pp. 96–108). The development of electric arc furnaces for steelmaking is described. A general description of a 70-ton furnace is given, including hearth design and materials, electrode manufacture, and control, and it is claimed that this is a particularly suitable method for the manufacture of stainless steels.—J. P. S.

The Kinetics of Combustion of Manganese, Silicon and Sulphur in Molten Iron. A. M. Samarin and L. A. Shvartsman. (Journal of Physical Chemistry, U.S.S.R., 1948, vol. 22, pp. 565–574 [in Russian]: Chemical Abstracts, 1948, vol. 42, Oct. 10, cols. 7145–7146). If the slag formed is immediately removed, the concentration c of manganese, silicon, and sulphur in molten iron in contact with air decreases according to $-dc/dt = kc$; k seems to be independent of temperature between 1570° and 1700°. For manganese it was shown that $k = k's/m$, s being the area of contact melt/air and m the mass of the melt. The values of k' were 1·56, 1·20, and 0·27 g./sq. cm. minimum for manganese, silicon, and sulphur. By assuming the rate of combustion to be determined by the rate of diffusion, and the diffusion coefficient of manganese in molten iron to be 9·60 sq. cm./day, the diffusion coefficients of silicon, nitrogen, carbon, and sulphur are 7·39, 3·26, 2·83, and 1·66 sq. cm/day respectively; the value for nitrogen is computed from the experiments by Chipman and Murphy. The thickness of the diffusion layer is about 0·1 mm.

Effect of Silicic Acid on the Equilibrium between Liquid Iron and the Simplest Basic Slags. O. A. Esin. (Journal of Physical Chemistry (U.S.S.R.), 1948, vol. 22, pp. 617–623: Chemical Abstracts, 1948, vol. 42, Sept. 20, col. 6717). The theory of perfect ionic solutions is applied to literature data on the equilibrium in the two-phase systems Fe, metal, O/FeO, metal oxide, and Fe, metal, O/FeO, metal oxide, SiO_2. In the absence of SiO_2, the theory is fulfilled when the metal is manganese, nickel, or cobalt, *i.e.*, a metal similar to iron in the dimension and polarizability of its ions. When the metal is calcium, electrostatic effects on the coefficient of activity must be taken into account. In the presence of SiO_2, even similar cations behave differently. This is attributed to a relatively regular structure within the slags.

Concerning the Possibility of the Existence of a Metal-Scale Surface Layer during Production of Steel. R. Zoja. (Metallurgia Italiana, 1948, vol. 40, Jan.–Feb., pp. 13–18: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 6). The possibility of the existence of such a layer was experimentally demonstrated.

PRODUCTION OF FERRO-ALLOYS

The Production of Ferro-Manganese from Low-Grade Ores. H. Reinfeld. (Iron and Steel Institute, 1949, Translation Series, No. 371). This is an English translation of a paper which appeared in Stahl und Eisen, 1948, vol. 68, Jan. 29, pp. 39–43 (*see* Journ. I. and S.I., 1948, vol. 158, Apr., p. 529).

The Stepped Reduction in Electric Furnaces of the Ores of Elements for Refining Steel. G. Volkert. (Archiv für das Eisenhüttenwesen, 1948, vol. 19, pp. 1–6). The published data on the reduction of bauxite, ilmenite, chromium ores, and manganese ores are discussed and some new work is reported. Iron and titanium could be separated from ilmenite on a production scale in an 800-kVA electric furnace using carbon as a reducing agent and forming a suitable slag. The H. Hahl and Krupp-Renn processes for recovering manganese from high-manganese iron ores are described. The former is a blast-furnace process with low-temperature blast (100–200° C.) and an acid slag. Manganese can be separated from manganese ores high in iron and phosphorus by a process in which silica is added to form $MnOSiO_2$; the process artificially increases the heat of formation of MnO, and this, in conjunction with the thin slag, helps to reduce it. R. A. R.

Ferro-Alloys for the Manufacture of Steel in Australia. W. Hewitt. (Proceedings of the Institute of Australian Foundrymen, 1942–43, vol. 3, pp. 47–67). *See* Journ. I. and S.I., 1943, No. I, p. 152A.

FOUNDRY PRACTICE

Netherlands Foundries. J. H. Ubbink. (American Foundryman, 1948, vol. 14, Aug., pp. 50–51). A brief survey is given of Dutch iron foundry practice.—J. C. R.

Engineering Compressed Air Installations to Meet Foundry Needs. (American Foundryman, 1948, vol. 14, Aug., pp. 52–56). An account is given of factors influencing the size of a compressed-air plant, its operation, and some of its applications in the foundry.—J. C. R.

Controlling Quality in Castings Production. V. A. Simpson and G. K. Eggleston. (American Foundryman, 1948, vol. 13, June, pp. 55–56). Various suggestions are made as to means by which the quality of castings may be improved and the number of rejects reduced.—J. C. R.

Cupola Working. M. Guédras. (Métallurgie, 1948, vol. 80, Nov., pp. 11, 13, 15). An account is given of the properties required in the refractory linings of cupolas, the factors that influence the working of cupolas, and the reactions that take place during melting.—J. C. R.

Blast Variations Seriously Affect Cupola Operations. B. P. Mulcahy. (American Foundryman, 1948, vol. 13, June, pp. 34–42). The author deals with the importance of an efficient air system in cupola practice and of the function of the blast in relation to the rate of combustion of the coke and the physical properties of the metal. The combustion reactions within the cupola are examined in detail.—J. C. R.

New Experience with Hot-Blast Cupolas. K. Roesch. (Neue Giesserei, 1948, vol. 33–35, Dec., pp. 165–169). Experience in the use of hot-blast cupolas in Germany is reported and the results obtained discussed. Two works making malleable iron produced 10–12 tons (metric)/hr./sq. m. of cupola section using 140 to 170 cu. m. of air per sq. m. of cupola section. Heat balance diagrams for cold and hot-blast cupolas are presented which show 30% thermal efficiency for the former and 50% for the latter. With blast at 480–500° C. the iron is 30–50° C. above the usual tapping temperature for cold-blast operation.—R. A. R.

The Effect of Hot Blast on the Combustion Process in the Cupola. O. Günthner. (Neue Giesserei, 1948, vol. 33–35, Dec., pp. 169–171). The course of the combustion in the hot-blast cupola is discussed from both theoretical and practical points of view. There is a minimum blast temperature below which hot-blast practice is uneconomic. The achievement of high blast temperatures without using heat from an external source depends upon the utilization of the chemically fixed heat of the shaft gases, since their sensible heat is normally sufficient to produce blast temperatures up to 300° C. which is insufficient for economic operation.—R. A. R.

Anthracite-Coke Mixtures Used in High Speed Cupola Melting. C. C. Wright and W. J. Reagan. (American Foundryman, 1948, vol. 14, Sept., pp. 37–44). Cupola performance was investigated using varying percentages of anthracite in three different sizes from four collieries in conjunction with two different cokes, in a cupola lined to 24 in. inside diameter and later relined to 30 in. dia. In the 24-in. cupola from 30% to 75% of anthracite in the charges was used at metal to fuel ratios as low as or lower than when all coke was used. Adequate quantities of metal were produced at unusually high melting rates per unit of cupola area, with temperatures and fluidities satisfactory for permanent mould casting, with no major change in operating routine and with low scrap losses. Tests made with 100% anthracite proved unsatisfactory. Fuel-bed resistance was higher than with coke alone, and was the limiting factor in determining the percentage of anthracite that could be substituted for coke. Anthracite operations were in general less flexible than when using coke alone and required closer control. In the 30-in. cupola at the high-melting rates required, performance depended on the quality of the coke with which the anthracite was used. Results obtained are tabulated and discussed.—J. C. R.

Cupola Operations with Anthracite. C. C. Wright and W. J. Reagan. (Pennsylvania State College, Mineral Industries Experiment Station, 1948, Technical Paper No. 137 : Chemical Abstracts, 1948, vol. 42, Oct. 10, cols. 7213–7214). Methods for accurately determining the temperature of molten iron and metal fluidity were investigated, as were high-speed melting operations using various sizes and types of anthracite and coke. Temperatures were measured with platinum/platinum-rhodium thermocouples cased in double fused-silica protection tubes. The protected couple was immersed in a well which was built into the cupola spout on the ladle side of the slag skimmer. Equilibrium was reached about 30 sec. after immersion, and approximately six to eight immersions were obtained before the outer tube needed replacement. The fluidity test mould consisted of a series of hairpin-shaped runs, 15 in. long, connected in series with a feeder gate and a riser. Melting tests were made in 24-in. and 30-in. cupolas. With a 6·5 : 1 ratio of metal to fuel in the 24-in. cupola, the melting rates secured with both coke and coke-anthracite mixes were in the range of 2·2–2·5 tons/hr. With anthracite-coke mixtures, pressures were somewhat higher than with coke alone but became excessive only when 50% or 75%, depending on the grade of anthracite, coal was used. With high percentages of anthracite, operations were less flexible with anthracite than with coke and required closer control and operating attention. In the 30-in. cupola at the high melting rates required, the performance was largely dependent on the quality of the coke with which the anthracite was used. With small-size coke the limiting quantity of anthracite was fixed by fuel-bed resistance at about 40%. With large foundry coke, up to 60% of the anthracite which normally showed the highest fuel-bed resistance was used satisfactorily. Metal analyses showed that no significant changes in metal composition occurred under normal operation over the regular 8 hr. of cupola operation. The metal composition was C 3·36–3·74%, S 0·052–0·084%, Mn 0·39–1·30%, Si 2·22–2·66%, and P 0·149–0·263%.

Production and Properties of Nodular Cast Iron (Nodulite)—A Bibliography. G. R. Woodward. (Bulletin and Abstracts of the British Cast Iron Research Association, 1948, July, pp. 200–202 ; BCIRA External Report No. 224 ; [Abridged] Iron Age, 1948, vol. 162, Nov. 25, p. 83). This is a survey of the literature on nodular cast iron, covering the papers published between March, 1947, and June, 1948 by Morrogh, Morrogh and Williams, Morrogh and Grant, Dickinson, and Pearce.—J. P. S.

Describes Electric Furnace Malleablizing Operations. H. R. Cowles. (American Foundryman, 1948, vol. 14, Sept., pp. 50–53). An account is given of operations at the Ashtabula plant of the Lake City Malleable, Inc., where high-grade annealed castings are produced in six pairs of 16-ton electric annealing furnaces and one pair of 4-ton furnaces. The 16-ton furnaces are the largest of the elevator batch type and are built in pairs. Castings to be annealed are loaded on the car and raised into the high-temperature furnace ; then, upon completion of the high-temperature treatment the car is transferred to the low-temperature furnace where faster cooling can be achieved by means of air cooling tubes.—J. C. R.

Induction Melting Furnaces. (Wire Industry, 1948, vol. 15, Nov., p. 743). Some of the induction melting furnaces, up to 1 ton in capacity, manufactured by Birlec, Ltd., Birmingham, are briefly described.—R. A. R.

Results of New Investigations Relating to Sands, Fireclays, and Clays. W. W. Magers. (Neue Giesserei, 1948, vol. 33–35, Dec., pp. 174–178). Results of investigations of moulding sands, fireclays, and clays, by C. W. Briggs, K. Endell, and F. Singer, are reviewed.—R. A. R.

Foundry Sands Evaluated. Natural Bonded *vs.* Synthetic Sands. C. A. Sanders. (American Foundryman, 1948, vol. 14, Sept., pp. 45–49). The properties of naturally bonded sands and synthetic moulding sands are outlined.—J. C. R.

A Moulding and Core-Sand Development. W. Bullock and J. Finlay. (Foundry Trade Journal, 1948, vol. 85, Nov. 18, pp. 481–482). The authors added 0·5% clay, 1·5% cereal binder and 3% black powdered or pelleted pitch to a washable silica sand. The mixture was then milled for 5 min. and water added up to 3%. The cores were dried at 285° F. (140°C.). Although they need not be coated, large cores gave best results when coated in the green state with a creamy solution of "Molochite" and water with 0·5% clay. Green cores can be dried at a very low temperature and more rapidly than an oil-sand core. Castings could be knocked out of the mould entirely clean of sand. The theory of the bonding practice is outlined.—J. C. R.

Chemically Coated Sand. A New Bonding and Refractory Process for Foundries. W. A. Turner. (Iron and Steel, 1948, vol. 21, Nov., pp. 483–484). Details are given of a new process "Westonite," in which iron-foundry moulding sand is coated with a non-thermosetting plastic carbon resin. The subsequent activation of that coating by chemical treatment provides new refractory characteristics and a new type of bonding action which augments the normal clay–water–sand system. The properties claimed for this sand are discussed.—J. C. R.

Developments in American Foundry Equipment. W. A. Turner. (Foundry Trade Journal, 1948, vol. 85, Nov. 25, pp. 509–512). Brief illustrated details are given of a new type of sandslinger, a continuous shot-blasting machine, a cartridge type core blower, a high-frequency drying oven, sand conditioning machines, and a chemically bonded sand using "Westonite," a thermoplastic hydrocarbon.
J. C. R.

Plastic Pattern Equipment. S. Denkinger, jun. (American Foundryman, 1948, vol. 13, June, pp. 43–45). An account is given of the properties and uses of plastic patterns in foundry practice.—J. C. R.

Designing and Rigging for Core Blowing. H. J. Jacobson. (American Foundryman, 1948, vol. 14, Aug., pp. 41–45). The author considers the various factors influencing the choice of design of core boxes and the material to be used for their manufacture.—J. C. R.

Evaluation of Core Knockout. (Transactions of American Foundrymen's Association, 1947, vol. 55, pp. 313–325). *See* Journ. I. and S.I., 1947, vol. 157, Oct., p. 293.

Moulding and Casting a 5-Ton Ingot Mould. J. Steele. (Institute of British Foundrymen, South African Branch: Foundry Trade Journal, 1948, vol. 85, Oct. 28, pp. 415–416). A short note is presented on the processes involved in moulding and casting a 5-ton ingot mould.—J. C. R.

Centrifugal Casting—Calculation and Feeding Pressures. W. A. Spindler. (American Foundryman, 1948, vol. 14, Aug., pp. 57–58).

New Mold Coating Widens Centrifugal Casting Use. J. Anthony. (Iron Age, 1948, vol. 162, Dec. 2, pp. 94–98). In the centrifugal casting of iron and steel pipe, a new type of mould coating is used; it provides a slightly rough, instead of a smooth, mould surface which reduces the effect of splashing when the molten metal first enters. This process is said to assist the production of duplex structures, such as white iron rolls with grey iron core, and steel tube lined with copper and intended for further drawing down. Certain grades of stainless steel, difficult to pierce for tube-making by conventional methods, may also be cast as hollow cylinders for further reduction.—J. P. S.

Mass Production of Precision Castings. (American Foundryman, 1948, vol. 14, July, pp. 46–49). An account is given of practice at the Allis Chalmers Manufacturing Co., Milwaukee, where precision castings are mass produced by means of the lost-wax process.—J. C. R.

Precision Castings—Production Methods for Steel and Cast Iron. F. Hudson. (Iron and Steel, 1948, vol. 21, Oct., pp. 427–430; Nov., pp. 475–477). An illustrated account is given of the various stages in the investment moulding method for the production of precision castings in steel. Brief reference is made to production methods for cast iron.—J. C. R.

Formation of Hot Tears in Steel Castings. H. Juretzek. (Neue Giesserei, 1948, vol. 33–35, Dec., pp. 172–174). The causes of the formation of hot cracks, or hot tears, in steel castings are discussed and examples are described. The way in which the strength of the moulding sand and the design of the mould affect crack formation is dealt with by references to the literature. The temperature at which the cracks form is usually in the 1250–1300° C. range for steel with 0·28% to 0·50% of carbon.—R. A. R.

A Mechanical Method for Machine Repair. T. O. Oliver, jun. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 515–518). *See* Journ. I. and S.I., 1948, vol. 158, Feb., p. 268.

HEATING FURNACES AND SOAKING PITS

New Heating Furnaces Boost Forging Output. H. Chase. (Iron Age, 1948, vol. 162, Nov. 18, pp. 113–116). A new type of furnace built by the George J. Hagan Co., Pittsburgh, for heating billets and forgings is oil-fired and has a rotary hearth. Each replaces two or three of the older box-type, yet the steel remains in the furnace 25–30% longer; a lower thermal head may thus be maintained, saving fuel and avoiding overheating of the steel. Where the box-type furnace still remains more suitable, doors have been redesigned to the minimum opening necessary for each size of billet.
J. P. S.

Heating Factory Furnaces with Flameless Gas. V. S. Gavripenko. (Promyshlennaia Energetika, 1948, May, pp. 9–11 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 38). Technical characteristics are presented of certain forging furnaces using flameless combustion.

Remote Control of Continuous Slab Heating Furnaces. C. E. Duffy. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 726–731). *See* Journ. I. and S.I., 1948, vol. 158, Apr., p. 530.

Heat Problems in the Steel Industry. V. Paschkis. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 283–287). *See* Journ. I. and S.I., 1947, Sept., p. 144.

Heating and Melting Furnace Controls. C. G. Bigelow, jun. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 312–317). *See* Journ. I. and S.I., 1947, vol. 157, Sept., p. 144.

Modern Furnaces for Mechanized Sheet Mills. P. Heurtey. (Métallurgie, 1948, vol. 80, Oct., pp. 19–21, 23, 25). The advantages and disadvantages of moving-chain, walking-beam, and roller-hearth reheating furnaces for sheet mills are considered and schemes for positioning the furnaces in relation to the mills stands are proposed. For reliable operation and the maintenance of production the author favours the moving-chain furnace.—R. A. R.

Mercury Arc Frequency Changing Equipment for Induction Heating. S. R. Durand. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 226–234). *See* Journ. I. and S.I., 1947, vol. 157, Sept., p. 145.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

The Heat Treatment of Iron and Steel—Recalescence. L. F. Keeley. (Machinery Lloyd (Overseas Edition), 1948, vol. 20, July 3, pp. 68–72: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 40). The author deals with the fundamental mechanisms of heat-treatment and the phase transformations accompanying it, including the phenomenon of increase in brightness at certain intermediate temperatures during gradual cooling from the incandescent state.

The Application of Salt Baths for the Treatment of Metals. Stempfel. (Société Industrielle du Nord de la France: Journal du Four Electrique, 1948, vol. 57, July–Aug., pp. 81–82). In this summary the author discusses the use of **S**-curves and salt baths for the heat-treatment of steels.—R. F. F.

Trends in Salt Bath Heat Treatment. H. J. Babcock. (Chicago Technical Conference: Steel Processing, 1948, vol. 34, Aug., pp. 435–438). Descriptions are given of salt-bath heat-treatment equipment in which the salt is heated by pairs of immersed electrodes. The operating costs and its advantages are discussed.—R. A. R.

Notes for Toolmakers on the Heat-Treatment of Steel. R. S. O'Hagan. (New Zealand Engineering, 1948, vol 3, July, pp. 669–672; Aug., pp. 769–774). After giving definitions of chemical and physical terms used in metallurgy, the theory and practice of heat-treatment are explained in a manner

suitable for technicians who have not had a scientific training.—R. A. R.

Heat Treating Stainless Steel by Salt Bath. L. Sanderson. (British Steelmaker, 1948, vol. 14, Nov., pp. 518–519). A new method for removing welding flux from welded stainless steel and annealing it is described. It consists of annealing in a sodium carbonate bath held at 900–1080° C. by immersed Inconel electrodes, and then pickling in weak acid. As the annealing and the pickling require only 5 min. each the process is very rapid and the cost is low.—R. A. R.

Heat-Treatment at Temperatures below 0° C. S. Jablonski. (Przeglad Mechaniczny, 1948, Feb.–Mar., pp. 70–76 [in Polish]: [Abstract] Mécanique Documentation, 1948, vol. 3, Oct., p. 11). The author has studied the decomposition of residual austenite; he outlines some practical applications of low temperatures in the treatment of tool steel and describes the equipment necessary for obtaining these low temperatures.

Industrial Heating. American Technique and French Industry. A. Bailly. (Orient. Techn. 1948, Apr.–May, pp. 77–79: [Abstract] Mécanique Documentation, 1948, Aug.–Sept., p. 11). A description is given of a modern continuous furnace for the annealing of blackheart malleable iron in a controlled atmosphere.

Dispersion Hardening of High-Alloy Austenite as a Factor of Its Heat Resistance. A. M. Borzdyka. (Bulletin de l'Académie des Sciences, U.R.S.S., Classe des Sciences Chimiques, 1948, Mar.–Apr., pp. 153–160 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 16). Processes of dispersion solidification of metallic gamma solid solutions of the systems Fe–Cr–Ni and Fe–Cr–Mn in connection with their mechanical strength at high temperatures, are described. Principles of rational utilization of such processes during the practical application of austenitic alloys under conditions of creep at high temperatures are outlined.

Magnetic Control of the Quality of the Heat-Treatment of Products Made from Chromium–Nickel–Vanadium Steels. M. N. Mikheev, P. N. Zhukova, and A. P. Voroshilova. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1210–1216). [In Russian]. Experiments are described in which the hardness, coercive force, maximum magnetic permeability, saturation magnetization, and specific electrical resistance of steel specimens were determined after various heat-treatments. Impact-type specimens 8 × 8 × 65 mm. were used, and the temperature was controlled to within 0·5–1·0% during heating. A chromium–nickel–vanadium steel and a chromium–vanadium steel were investigated. The results obtained are presented, together with some illustrations of microstructures, and it is concluded that, under suitable conditions, the quality of heat-treatment of the above steels can be controlled on the basis of magnetic and electric tests. S. K.

The Preparation of Gas-Carburizing Atmospheres in France. J. Pomey and M. Chateau. (Société Française de Métallurgie, Oct. 9, 1947: Revue de Métallurgie, Mémoires, 1948, vol. 45, Sept., pp. 323–342). First attempts to use an American gas-carburizing plant with butane instead of natural gas were not successful. The authors then turned to wood producer gas reduced by charcoal at 1000° C., and soon achieved good results in the laboratory. At the same time the need to keep the American plant in operation led the authors to study also the preparation of the gas by catalytic oxidation of hydrocarbons. The resulting improvements were applied to the American plant, while the Renault process was also put into service. In the present article the authors discuss gaseous cementation in $CO–H_2–CH_4$ mixtures and by hydrocarbons and cyanogen, and describe the preparation of cementation atmospheres starting with gaseous hydrocarbons, the properties and preparation of reduced wood producer gas, the preparation of the " added " hydrocarbons, and the control of the gas-cementation process (temperature of reduction, thermal conductivity and calorific value of the gas, and continuous determination of the CO_2).—A. E. C.

Problems of the Carburization and Decarburization of Steel. F. E. Harris. (Société Française de Métallurgie, Oct. 9, 1947: Revue de Métallurgie, Mémoires, 1948, vol. 45, Sept., pp. 346–358). The diffusion of carbon and the factors governing it in the carburization and decarburization of steel are discussed.—A. E. C.

Flame Hardening Methods and Techniques. J. R. Burg. (Welding Journal, 1948, vol. 27, Oct., pp. 805–809). Flame-hardening is employed at the Baldwin Locomotive Works, Eddystone, Pa. in preference to case-carburizing or cyaniding because of the simplicity of the process, and the speed and economy of the short time cycle. Moreover, the wide variety of shapes, and the selective carburizing required in many cases in locomotive work, are better dealt with by the process. Much of the gear described is of local design and is as fully automatic as possible.—J. P. S.

Soluble Oil in Flame Hardening Operations. S. Smith. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 598–602). *See* Journ. I. and S.I., 1948, vol. 158, Feb., p. 270.

The Possibilities of High-Frequency Heating. K. G. Grönінger. (Pro-Metal, 1948, vol. 1, No. 6, pp. 271–279). The principles of high-frequency heating are simply explained and high-frequency current generators and many types of heating coil are described, special attention being given to the heat-treatment of lathe tools.—R. A. R.

High-Frequency Induction Heating in Sweden. L. Dreyfus. (International Congress of Mechanical Engineering, Paris, 1948: Iron and Coal Trades Review, 1948, vol. 157, Nov. 5, pp. 1015–1019). The author deals with the design of Swedish high-frequency furnaces for induction heating, which are operated mainly at rotary-generator frequencies up to 40,000 cycles/sec.; these are of a robust and reliable construction. The use of electronic generators is reserved for heat-treatment of small parts or surface hardening to a depth too shallow to be achieved by means of rotary-generator frequencies.

High Frequency Induction Surface Hardening. J. F. Libsch. (Steel, 1948, vol. 123, Nov. 15, pp. 97–102, 106). The principles of induction hardening, the apparatus required, and the type of result obtained are explained.—J. P. S.

Methods of Cooling Small Forged Parts. A. I. Sorokine and V. N. Smirnov. (Vestnik Machinostroenia, 1948, Feb., pp. 31–37 [in Russian]: [Abstract] Mécanique Documentation, 1948, vol. 3, July, p. 6). Different methods of cooling small forgings, according to their chemical composition, are discussed.

FORGING, STAMPING, DRAWING AND PRESSING

Fundamentals of Forging Practice. W. Naujoks. (Steel, 1948, vol. 122, June 7, pp. 101–104, 129, June 21, pp. 98–102; vol. 123, July 5, pp. 76–79, 104; July 19, pp. 99–100, 102, 128, Aug. 2, pp. 91–98; Aug. 16, pp. 94–97; Aug. 30, pp. 59–63, 86; Sept. 13, pp. 100–103, 126; Sept. 27, pp. 89–91; Oct. 11, pp. 101–104, 123; Oct. 25, pp. 78–84, 87; Nov. 8, pp. 96–100, 126–129; Nov. 22, pp. 68–71, 110; Dec. 6, pp. 121–127, 158–162). The first part of this article briefly describes the development of forging from hand methods, through the use of water power to steam and drop hammers, and the use of dies. Hand-forging techniques and the necessary tools are described in the second part with some illustrated examples, and the third part deals with upsetting, punching and forging of rings, and general drop-forging technique. In the fourth part rules for the design of dies and punches for progressive die-forgings are given. The fifth part describes helve hammers, drop hammers, board-, steam- and air-operated hydraulic forging presses, forging machines, and forging rolls. The sixth part is concerned with heating furnaces and control equipment, and the seventh with the manufacture of die-blocks and tools. The selection of steels for this purpose and the laying out and machining of blocks are considered. In the eighth part tools for cutting, shearing, sawing, trimming, and punching are described, and reference is made to the necessity of allowing for 'spring back' in pressing from sheet. The ninth part deals with heat-treating processes, and the cleaning of forges, the tenth is concerned with inspection and non-destructive and mechanical testing. In the eleventh part, the author considers the choice of materials for forging, discussing the uses of low- and medium-carbon steels, alloy steels both structural and heat- and corrosion-resistant, and of non-ferrous alloys, and copper, nickel, and aluminium alloys. The twelfth deals with the design of dies to obtain proper draft, the proper filling of fillets and radii, ribs and thin sections, and bosses and other projections, and the thirteenth extends these considerations to press forging. The advantages of machining forgings in the normalized state are compared with those of machining in the hardened and tempered state. The final article in the series gives a glossary of terms employed in the forging industry.—J. P. S.

Selection of Steels for Forging. L. F. Spencer. (Steel Processing, 1948, vol. 34, June, pp. 297–301, 305; July, pp. 366–368; Aug., pp. 427–431; Sept., pp. 479–482). The defects arising during processes of steel manufacture which can affect subsequent forging are outlined. The suitability for forging and the properties of forged plain carbon steels, manganese, manganese–vanadium, and molybdenum steels, and the low-alloy chromium and nickel steels with and without additions of vanadium and molybdenum are discussed.—R. A. R.

Modern Cold Forging Practice. J. H. Friedman. (Iron Age, 1948, vol. 162, Nov. 11, pp. 98–105). A wide variety of parts in ferrous and non-ferrous alloys can be made on cold-heading machines. Numerous illustrations of the type of work are given.—J. P. S.

The Manufacture of Bolts and Nuts. R. C. Rhoades. (Steel Processing, 1948, vol. 34, July, pp. 351–355; Aug., pp. 423–426). The requirements of steel for cold heading are mentioned and descriptions are given of cold heading and hot forging bolts, the cold punching and cold forging of nuts, and the roll-threading of bolts in the Waterbury-Farrel machine. R. A. R.

How Packard Whips Tough Forging Jobs. G. F. Daschke and H. Lawson. (Machinist, 1948, vol. 92, Nov. 20, pp. 973–977). The methods used by the Packard Motor Car Co., for die-forging some difficult shapes are described.—R. F. F.

Stamping Buick Bumper Guards. H. Chase. (Iron Age, 1948, vol. 162, Nov. 25, pp. 90–91). At the Syracuse, N.Y., plant of Brown-Lipe-Chapin Division of General Motors Corp., bumper guards are deep-drawn from $\frac{3}{32}$-in. sheet, formed, trimmed and cleaned; fixing studs are then welded on. J. P. S.

Automatic Spinning of Stainless Steel. A. Hildebrandt. (Tool Engineer, 1948, vol. 21, Sept., pp. 20–22: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 36). The procedure is outlined for the production of cones for television cathode-ray tubes from Type 446 stainless steel.

Processing and Fabrication of Stainless Steel Sheet and Plate Products. H. S. Schaufus, I. C. Clingan, and W. H. Braun. (Steel Processing, 1947, vol. 33, Apr., pp. 219–224; Nov., pp. 681–684, 704; 1948, vol. 34, Aug., pp. 412–415, 431). Conclusion of a series of articles (*see* Journ. I. and S.I., 1946, No. II, p. 52A). The pressing, spinning, welding, and soldering of stainless steel are described and many of its applications are reviewed and illustrated.

Forging Die Design. J. Mueller. (Steel Processing, 1948, vol. 34, Aug., pp. 409–411, 426). The design of dies for trimming and straightening small forgings is discussed.—R. A. R.

Die-Setting and Economical Punch-Press Operation. E. H. Girardot. (Iron Age, 1948, vol. 162, Nov. 18, pp. 94–97.) The dangers of misaligned punches and dies are dealt with and a training programme for operators is outlined.—J. P. S.

The Tools for Pressing and Drawing Shops. J. Senn. (Pro-Metal, 1948, vol. 1, No. 6, pp. 241–256). The design and manufacture of all kinds of dies for extrusion and drawing are described and illustrated.—R. A. R.

Drawing Stainless Steel Milker Pails. W. Ellingboe. (Iron Age, 1948, vol. 162, Nov. 11, pp. 94–97). The deep-drawing of 18/8 stainless steel into milk pails is described. There are four drawing stages, with annealing after each two draws. The final forming operation is a hydraulic 'bulging.' Polishing, the soldering on of a base ring, and the spot-welding of a handle complete the operation.—J. P. S.

Continuous Steel Processing Machines. R. Saxton. (Power Transmission, 1948, vol. 17, Aug. 15, pp. 814–816: [Abstract] PERA Bulletin, 1948, vol. 1, Nov., p. 759). This article is a short review of the process of steel wire manufacture and the associated machinery.

Drives for Automatic Speed and Tension Control in Wire Processing Equipment. N. J. Ranney. (Wire and Wire Products, 1948, vol. 23, Aug., pp. 676–679, 700–702; Sept., pp. 763–768, 802, 803). Examples of electrical, mechanical, and hydraulic tension control equipment for high-speed wire mills are described and illustrated.—R. A. R.

The Wire-Drawers' Craft as Practised in the Warrington District. G. K. Rylands and A. E. Sykes. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 363–364). A description is given of hand methods of making a wire-drawing plate as practised at Warrington before the advent of the tungsten carbide die.—R. A. R.

Wire Drawing Research in the British Iron and Steel Research Association. W. C. Hessenberg. (Wire and Wire Products, 1948, vol. 23, Oct., pp. 904–907, 980). Research work on wire-drawing by the British Iron and Steel Research Association is reviewed. Papers by J. G. Wistreich and by G. D. S. MacLellan in the *Journal* are referred to. A series of photos of the internal surface of a hard carbide die showing the formation of a ring with increasing lengths of drawn wire, and a micrograph showing how the carbide particles in the region of the ring tend to crack and fall out, are reproduced.—R. A. R.

The Control and Production of High Carbon Wire. J. G. Weiss. (Wire and Wire Products, 1948, vol. 23, Oct., pp. 884–887, 994). The sequence of processes and precautions to be taken in the manufacture of high-carbon steel wire are described.—R. A. R.

Wire Drawing Speed Increased 25%. (Steel, 1948, vol. 123, Nov. 8, pp. 102, 132). "Banox," an amorphous metaphosphate compound, is used in wire-drawing by the Jones and Laughlin Steel Corp. It is found to have excellent rust-resisting properties. and to act as a lubricant; when wire is coated, by dipping with "Banox" before liming, it is found that the amount of lime applied is no longer critical. It can also be used with wire flash-coated with copper, where it assists rust proofing.—J. P. S.

New Phosphate Material Used for Wire-Drawing. (Steel Processing, 1948, vol. 34, Sept., pp. 475–476). The advantages of the Banox phosphatizing process as a preliminary treatment before fine-drawing high carbon steel wire are discussed. R. A. R.

The Shape of Wire-Drawing Dies in Relation to the Drawing Effort and Friction Conditions. E. Siebel, N. Ludwig, and P. Melchior. (Engineers' Digest (London), 1948, vol. 9, Dec., pp. 398–400). This is an abridged translation of an article which appeared in Werkstatt und Betrieb, 1948, vol. 81, July, pp. 177–180. (*See* Journ. I. and S.I., 1948, vol. 160, Dec., p. 440).

Practical Application and Mill Practice with Carbide Dies. E. T. Miller. (Wire and Wire Products, 1948, vol. 23, Oct., pp. 910–913). The design of tungsten carbide wire-drawing dies is discussed. The present American standard nib sizes are given and it is suggested that the nib length should be increased so as to provide proportions which would permit a greater number of recuts as the nib becomes worn.—R. A. R.

Modern Electrical Control for Wire Mill Machinery. O. M. Bundy. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 603–610). *See* Journ. I. and S.I., 1948, vol. 158, Feb., p. 271.

History and Progress of Wire Coatings. H. L. Trembicki. (Wire and Wire Products, 1948, vol. 23, Sept., pp. 762, 794, 795). Failures and success in the development of coating materials, containing no lime, to carry the lubricant in wire-drawing are reported. The coating compound to replace lime should be of low *p*H with no free alkali; it should contain a water-soluble binding and carrying agent and should not require baking. Such a coating containing borates has been developed.—R. A. R.

Practical Development of Modern Wire Drawing Compounds. E. L. H. Bastian. (Wire and Wire Products, 1948, vol. 23, Oct., pp. 890–894, 962, 963). The lubricants which are used for drawing steel and non-ferrous metal wire are discussed with recommendations on the types to use for carbon steel and stainless steel.—R. A. R.

Fumes and Ventilation in the Wire Mill. W. G. Imhoff. (Wire and Wire Products, 1948, vol. 23, Oct., pp. 895–903, 1000). Recommendations are made on ventilation systems for wire mills which incorporate a pickling shop.—R. A. R.

ROLLING-MILL PRACTICE

Choice of Type of Current, Size of Voltage and System of Electric Drive for Mechanization of Rolling Mills. N. A. Tishchenko. (Vestnik Elektropromyshlennosti, 1948, No. 6, pp. 3–13 [in Russian]: Electrical Engineering Abstracts, 1948, vol. 51, Dec., p. 318). The following types of drive are described: (1) Ward-Leonard systems used for motors above 80 kW. and catering for over 500–800 reversals; (2) D.C. motors with rheostat-contactors for application with 1 : 4 speed variation; (3) squirrel-cage induction motors of 20–30 kW. for smaller installations; and (4) individual "roll-gang" motors fed from 380 V. or frequency converters, this last method is rapidly becoming popular. Power require-

ments, efficiency, and reliability of the various systems are compared.

Twin-Motor Drives for Cold Mills. R. H. Wright. (Iron and Steel Engineer, 1948, vol. 25, Sept., pp. 125–133). The author traces the development of the use of twin-motor drives for cold mills, and explains the theory underlying their use. In the discussion the advantages claimed for these drives are debated at length.—J. C. R.

Speed Stability of Motors for Continuous Mills. F. E. Crever and T. M. Linville. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 318–328). *See* Journ. I. and S.I., 1947, Sept., vol. 157, p. 146.

Resistance Strain Gauges for the Measurement of Roll Strain, Torque, and Strip Tension. J. Rankine, W. H. Bailey, and F. P. Stanton. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 381–387). The methods of measuring roll separating force, spindle torque, and strip tension in the 10 in. × 10 in. two-high experimental cold-rolling mill at Sheffield University by the use of resistance strain gauges are described and illustrated. The tension meter consists of a combination of a torque meter and a device which automatically divides the value of the torque by the coil radius. The equipment operates on direct current at 100 V. which can be supplied from dry batteries. Electronic equipment is limited to one single-valve D.C. amplifier which is used only when measuring very low tensions. The values of torque and tension are indicated on 2½-in. pointer meters, the readings of these and similar meters indicating other variables being recorded simultaneously by a 35-mm. cinematograph camera equipment.

Graphical Method of Designing Roll Passes. Z. Wusatowski. (Iron and Steel Institute, 1948, Translation Series, No. 362). This is an English translation of a paper which appeared in Hutnik, 1947, vol. 14, Apr., pp. 206–219. The author describes, with examples, a graphical method for the rapid design of passes for rolling rounds and squares, as well as for roughing-mill rolls.—R. A. R.

Roll Neck Seals—Their Development and Application. F. E. Payne. (Steel, 1948, vol. 123, Nov. 29, pp. 92, 94, 98, 102). Historical developments in roll-neck oil seals are described which were based on improvements of seals used in other industries. A new type of seal is described which has been specially designed for the purpose; this seals in the vertical plane, is easy to instal, and can be used with either plain or roller bearings. Increased bearing life, freedom from staining of strip by lubricant, and increased roll life are claimed.—J. P. S.

Recent Developments in Steel Processing. J. A. Kilby and W. G. Cameron. (Transactions of the Institution of Engineers and Shipbuilders in Scotland, 1947–48, vol. 91, pp. 81–139). After giving brief descriptions of soaking pits and reheating furnaces for ingots and billets, detailed descriptions are presented of several types of rolling-mills stands, mill layouts, drives, and auxiliary machinery, many of which are shown in thirty-two line-drawings.—R. A. R.

Heating and Rolling Low Carbon Steel for Strip. N. E. Rothenthaler. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 465–472). *See* Journ. I. and S.I., 1947, vol. 157, Dec., p. 638.

Making While Mending. Section Mill Reconstruction at Appleby-Frodingham While Maintaining Output. (Iron and Steel, 1948, vol. 21, Nov., pp. 463–467: Iron and Coal Trades Review, 1948, vol. 157, Dec. 31, pp. 1471–1473: British Steelmaker, 1949, vol. 15, Jan., pp. 10–14). The section mill plant at the Frodingham works of Appleby-Frodingham Steel Co. was recently reconstructed under the following conditions: Production had to be kept going; the existing site had to be used; and the existing mechanical cooling bed, roller-straightening machines, and other finishing and loading equipment had to be retained in the same positions. The reconstruction plan was as follows: (1) To instal a new 42-in. cogging mill; (2) to turn the section mill end for end and move it back to align with the new mill; (3) to replace the steam mill engines with electric drives; (4) to provide new racks and runouts to connect up with the mechanical cooling bed; and (5) while all that was going on, to erect a new mill building over the plant. The new plant is illustrated and described.—J. C. R.

New High Speed Rod Mill Utilizes Electronic Speed Regulation. G. M. Harvey and D. M. Allison. (Steel, 1948, vol. 123, Dec. 6, pp. 134–138). A rod mill built by Morgan Construction Co., Worcester, Mass. for rolling rods of from No. 5 gauge to ¾ in. dia. from 2½-in. square billets employs 19 stands in tandem; nine D.C. motors are used. Speed control is effected by means of a pilot generator coupled to each motor; any change in the voltage generated by this is electronically amplified and applied by means of a Rototrol to a booster generator in the motor circuit. To control the reel speeds, a similar method, employing a Rototrol but no amplifier, is employed whereby variations in the pilot-generator voltage affect the shunt field of the reel motors.—J. P. S.

The Electrification of the Cold Reduction Mill of the Columbia Steel Mill. F. R. Grant. (Blast Furnace and Steel Plant, 1948, vol. 36, Nov., pp. 1347–1354). A new 56-in. five-stand tandem cold reduction mill with associated processing lines for the production of high-grade tinplate and sheet has been installed at Columbia Steel Company, Pittsburg, California. The motors, power-supply, and control gear for the mill are described, together with the apparatus for maintaining constant tension and gauge.—J. P. S.

The Sendzimir Cold Strip Mill. A. I. Nussbaum. (British Steelmaker, 1948, vol. 14, Oct., pp. 458–462). The principles of the Sendzimir cold strip mill are explained and its advantages discussed. This is a cluster mill with six large outer rolls, four intermediate rolls, and two small work rolls. A 36-in. wide Sendzimir mill is now producing 1500 tons/month of extra light gauge stainless sheet and strip in final thicknesses ranging from 0·004 to 0·078 in.—R. A. R.

Producing Wide Stainless Steel Sheets at Republic Steel Corporation's New Plant. (Machinery (N.Y.), 1948, vol. 55, Sept., pp. 205–206: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 36). The processes described include cold reducing, annealing, pickling, slitting, and cutting.

Republic's New 48 in. Mill at Youngstown, Ohio. T. J. Ess. (Iron and Steel Engineer, 1948, vol. 25, Sept., pp. 69–71). An illustrated description is given of a new 48-in. strip mill at the Youngstown plant of the Republic Steel Corporation. The mill was made by adding three four-high finishing stands and coiling equipment to an existing 84-in. plate mill. It has a capacity of 60,000 tons per month of skelp and strip.—J. C. R.

The Uni-Temper Mill. A. I. Nussbaum. (British Steelmaker, 1948, vol. 14, Nov., pp. 503–508). The final stage, *i.e.*, temper rolling, of strip steel for tinplate production is described with special reference to factors governing the design of the latest type of mill for the purpose. This consists of two two-high mills in one stand. Numbering the rolls from top to bottom 1 to 4, Nos. 2 and 3 have no vertical adjustment and are driven; No. 1 is moved by a screw-down, No. 4 by a screw-up and both are idle. With this design the free span of strip between mills, in which the controlled elongation takes place, can be kept down to 10–15 in. The relative speed of the two mills is very accurately controlled by an electronic amplidyne system to maintain the required elongation at all speeds from starting up to about 3000 ft./min. Details of power consumption and quality of the strip produced are given.—R. A. R.

Machinery for Roller Leveling Flat Rolled Metal. A. J. Wardle, jun. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 329–333, 336). *See* Journ. I. and S.I., 1947, vol. 157, Sept., p. 146.

MACHINERY FOR IRON AND STEEL PLANT

Steel Plant Service Requirements for Cranes. I. E. Madson (Iron and Steel Engineer, 1948, vol. 25, Sept., pp. 96–99). Data are presented showing, for each of the following classes of crane, the average number of hours' operation in one year, the percentage time in use in an operational hour, and the number of moves per hour: Coking plant and blast-furnace cranes, open-hearth and electric furnace cranes, ingot-handling cranes, rolling-mill cranes, finishing-mill cranes, and miscellaneous cranes. The data were collected during asurvey of the service requirements of cranes in use in steel plants.—J. C. R.

Plain Sleeve Bearings. (Product Engineering, 1948, vol. 19, Oct., pp. 129–160). A comprehensive survey is presented of information on plain sleeve bearings. It is divided into sections dealing with performance factors, design concepts, bearing types and their characteristics, engine bearing requirements, materials, current design, porous bearings, and bearings of wood, graphite, cast iron and steel, plastics, and rubber.—R. A. R.

Bearing Construction and Performance Characteristics. E. Crankshaw and K. Scheucher. (Iron and Steel Engineer, 1948, vol. 25, Sept., pp. 109–119). The authors discuss the properties and characteristics of various bearing materials, their performance in service, and causes of failure.—J. C. R.

LUBRICANTS AND LUBRICATION

Lubrication Equipment Maintenance. R. A. Kraus. (Iron and Steel Engineer, 1948, vol. 25, Sept., pp. 100–108). The author describes the development of an organized lubricating equipment maintenance department, and its duties, with some examples of the scope of its functions.—J. C. R.

Barium Lubricating Grease. C. J. Boner and G. W. Miller. (Iron and Steel Engineer, 1948, vol. 25, Sept., pp. 120–124). The authors discuss the characteristics and applications of barium lubricating greases, which combine water-resistance with melting points up to 400° F.—J. C. R.

Centralized Lubrication in Industry. E. I. Pfaff. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 204–211). *See* Journ. I. and S.I., 1947, vol. 157, Oct., p. 295.

Metal Powder Self-Lubricating Bearings. A. J. Langhammer. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 46–50). *See* Journ. I. and S.I., 1947, vol. 156, May, p. 136.

Analysis of Centralized Lubricating Systems. J. P. Gravenstreter. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 153–161, 169). *See* Journ. I. and S.I., 1947, vol. 157, Oct., p. 295.

Roll Oil Emulsion for Cold Strip Rolling. R. W. Piper. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 398–400). *See* Journ. I. and S.I., 1947, vol. 157, Dec., p. 638.

Surface Activity of Lubricants. J. M. Wilson. (Proceedings of the Association of Iron and Steel Engineers, 1947, pp. 435–442). *See* Journ. I. and S.I., 1947, vol. 157, Dec., p. 639.

WELDING AND FLAME-CUTTING

Development of Welding Rods for Iron and Steel Welding. K. L. Zeyen. (Zeitschrift des Vereines deutscher Ingenieure, 1948, vol. 90, June, pp. 185–190). Developments in welding rod materials in England, the U.S.A., and the U.S.S.R. since 1939 are reviewed.—R. A. R.

The Comparative Behavior of Mild Steel Welds Made with E 6010 and E 6016 Electrodes. F. W. Daniels, F. S. Gardner, and R. M. Rood. (Welding Journal, 1948, vol. 27, Sept., pp. 436-s–440-s). The 'E 6016' electrode has a lime type of coating intended to contain, or release in use, less hydrogen than the 'E 6010' which has a cellulose coating. Tests have been made with these two electrodes to compare the tensile and impact properties of the welds produced and to note the effect on ductility in each case of post-heating the welds. It was found that the tensile properties and elongation of welds produced with the two electrodes are nearly identical, that 'fish-eyes' denoting the presence of hydrogen occur in equal degree in tensile fractures, but that the transition temperature of 'E 6016' welds is 75°–100° F. (43°–56° C.) lower than in 'E 6010' welds. The ductility of welds with both electrodes is increased from 24% to 38% by post-heating of welds, but impact properties are not improved; fish-eyes do not occur in Charpy impact specimens in welds with either material. Preheating of welds produces no significant increase in yield point or ultimate tensile stress and only a slight increase in elongation.—J. P. S.

Survey of Automatic Arc and Gas Welding Pressures as Used in the Automotive Industry. (American Welding Society, 1948, Pamphlet). A compilation of information on the use of automatic welding processes, including submerged-arc, atomic hydrogen, shielded metal-arc, bare metal-arc, carbon-arc, inert-gas metal-arc, and oxy-acetylene welding is presented. Factors involved in each process such as setting-up, current, backing, edge preparation, and speed of welding are dealt with.—R. E.

Coating of Steel Electrodes for Welding Cast Iron. P. S. Elistratov. (Avtogennoe Delo, 1948, Apr., pp. 17–19 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 42). Coatings of different compositions were investigated and the optimum composition was established from the data obtained.

Welding Electrode Coatings—Their Plasticity and the Ability to Press Them. W. Hummitzsch. (Werkstatt und Betrieb, 1948, vol. 81, Dec., pp. 337–345). Many factors affect the ability to press or extrude electrode coatings. The amount of solid or liquid plasticizer added is of great importance. Kaolin and rutile are solid plasticizers and waterglass is a liquid one. The mixture attains its maximum plasticity under pressure with quite small additions of liquid plasticizer, as has been shown by tests with the Brabender Plastograph, an instrument which has proved its value in determining the properties of electrode coating materials. Data are presented on the effect of different plasticizers on pressure and extruding rates of various coating mixes.—R. A. R.

Powdered-Iron Electrodes. I. Influence of Degree of Dispersion and of Composition of the Iron Powder on the Properties of Iron Electrodes. L. L. Kuz'min and L. V. Borisova. (Journal of Applied Chemistry, U.S.S.R., 1948, vol. 21, Apr., pp. 378–388 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 14). The properties of iron electrodes depending on method of production of the powder by hydrogen reduction of iron oxide are discussed.

Sulphur Reaction and Hot Cracking during Autogenous Welding of Low-Carbon Steel under a Flux. K. V. Lyubavskii. (Avtogennoe Delo, 1948, No. 2, pp. 15–20: Chemical Abstracts, 1948, vol. 42, Sept. 20, col. 6732). Rimming steel containing 0·51% of manganese and 0·022% of sulphur was welded with various types of electrodes and fluxes. The use of a high-manganese oxide flux or of a manganese-bearing electrode prevented conversion of manganese sulphide into iron sulphide during welding and decreased the susceptibility of the weld to hot cracking.

Investigations Concerning Oxygen and Nitrogen in Arc Welding with Coated Unalloyed Electrodes. F. Bischof. (Die Technik, 1948, vol. 3, Sept., pp. 407–409). The manner in which the ratio of FeO in weld metal to FeO in the slag was affected by the basicity of the slag was studied using unalloyed steel electrodes with basic and acid coatings. The value of this ratio increased with increasing slag basicity. The oxygen taken up by the metal was practically independent of the slag basicity, whilst the FeO content of the slag was dependent on slag basicity. Test data from the literature are plotted and curves constructed which show that increasing the thickness of coating and the slag basicity decreases the amount of nitrogen taken up.—R. A. R.

Some Aspects of the Metallurgy of Resistance Welding. M. A. Leroy. (Métallurgie, 1948, vol. 80, Nov., pp. 17. 19–21, 23). The author discusses the behaviour of the metal in resistance welding, the preparation of the surfaces, and the metallography of the joints obtained.—J. C. R.

Spot Welding of SKhLF Steel. A. S. Gel'man and S. S. Astaf'ev. (Avtogennoe Delo, 1948, Apr., pp. 1–10 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 42). Spot welded specimens of the above steel (C 0·12%; Si 0·31%; Mn 0·52%; S 0·03%; P 0·10%; Cr 0·55%; Ni 0·45%; Cu 0·68%) were investigated and optimum conditions for welding were established. Mechanical properties of the specimens are given.

The Welding of Corrosion-, Acid-, and Heat-Resisting Steels. W. Hummitzsch. (Schweisstechnik, 1948, vol. 2, Oct., pp. 119–128). After briefly discussing the microstructure of the high alloy corrosion-, acid-, and rust-resisting steels, the author gives details of the techniques and welding rods for welding them.—R. A. R.

Aids for Hardfacing. M. Riddihough. (Welding, 1948, vol. 16, Sept., pp. 390–397). Descriptions with numerous illustrations are given of equipment and methods for preheating and hard-surfacing parts by welding. The equipment includes gas burners, rotating jigs, and preheating furnaces; the processes include depositing Stellite by welding.—R. A. R.

Argon-Arc Welding of Thin Stainless Steel Sheets. A. Ya. Brodskii. (Avtogennoe Delo, 1948, May, pp. 6–8 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 44). A new method is described which, because of its high efficiency, absence of the necessity for using fluxes, and high strength and corrosion resistance of the welds, is very suitable for stainless steel sheets 1 mm. to 1·5 mm. thick.

Design and Fabrication of Welded Light Weight Pressure Vessels. J. J. Chyle. (Welding Journal, 1948, vol. 27, Oct. pp. 831–837). The welding and testing of light-weight pressure vessels of high-tensile steel are described. Submerged-arc

and inert-gas-shielded arc methods are favoured. Tests of the finished article include a hydrostatic bursting test, and a 150-ft. drop test.—J. P. S.

Welding for Porcelain Enameling. L. K. Stringham. (Iron Age, 1948, vol. 162, Dec. 16, pp. 90–94). Early use of arc welding in the fabrication of parts intended for subsequent enamelling frequently led to the formation of bubbles or stripped coatings; this was due to the absorption of hydrogen by the weld metal. The development of lime-ferritic electrodes with a coating free from hydrogen-producing materials, and the use of submerged-arc welding, have removed this difficulty. Welding procedures are described, together with certain precautions to be taken, such as the insistence on absolute freedom from contamination of the granular welding flux.—J. P. S.

Effect of Weld Metal Composition on the Strength and Ductility of 15% Cr–35% Ni Welds. D. Rozet, H. C. Campbell, and R. D. Thomas, jun. (Welding Journal, 1948, vol. 27, Oct., pp. 481-s–491-s). Tensile tests with all-weld-metal specimens have shown that there are optimum composition limits for carbon, silicon, manganese, sulphur, and phosphorus in the weld metal used on 15/35 chromium–nickel steels. Carbon should not be higher than 0·20%, silicon 0·40% max., manganese 1·0–2·0%, and sulphur and phosphorus should both be below 0·025%. Where silicon is raised to 1·5%, as in castings for elevated temperature service, carbon should be raised to 0·40% to avoid hot tears and fissures. It is found that while niobium may reduce the tendency to fissures it also reduces the ductility, and is not considered necessary.—J. P. S.

Influence of Sheet or Plate Thickness on Butt Weld Bend Tests. N. Ludwig. (Engineers' Digest (London) 1948, vol. 9, Dec., pp. 417–418). This is an abridged English translation of an article which appeared in Werkstatt und Betrieb, 1948, vol. 81, July, pp. 181–183. (*See* Journ. I. and S.I., 1948, vol. 160, Nov., p. 327).

Keeping the Mills Rolling. F. J. Gaydos. (Welding Engineer, 1948, vol. 33, Aug., pp. 35–38: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 50). The author deals with hard facing and building-up practices as important phases of welding maintenance in a steel mill.

Welding in Steel Plant Maintenance. T. W. McAuley. (Canadian Metals and Metallurgical Industries, 1948, vol. 11, Aug., pp. 19–22, 40–42). The maintenance work by welding which is described includes making hollow tie bars up to 11 ft. long to act as water-cooled ties for the walls of open-hearth furnaces, making cable guides of rail-steel plates welded with 25/12 chromium–nickel steel electrodes, making shoes for coke-oven pushers, repairing ore-bucket lips, and making mill feed rollers.—R. A. R.

Submerged Arc Welding for Maintenance. C. C. Keyser. (Iron and Steel Engineer, 1948, vol. 25, Sept., pp. 37–42). A description is given of a submerged-arc-welding process for maintenance work in steel mills, with an indication of its fields of application.—J. C. R.

Mechanical Properties of Joints Made by Gas Pressure Welding during Construction of Main Pipe Lines. A. S. Fal'kevich. (Avtogennoe Delo, 1948, Apr., pp. 20–22 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 42). Conditions are given for welding low-carbon steel pipe made of thin longitudinally welded sheets. Mechanical properties of welded joints are detailed.

Influence of Heat Treatment on the Strength of Spot Welds in "Chromansil" Steel. F. E. Tret'yakov. (Avtogennoe Delo, 1948, Apr., pp. 25–26). [In Russian].

The Impact Strength of Single-Bead Arc Weld Deposits as Affected by Temperature. R. Eisenberg and R. J. Raudebaugh. (Welding Journal, 1948, vol. 27, Sept., pp. 433-s–435-s). Tests on weld metal were made by filling up a U-groove in a plate and cutting strips at right angles to this groove; a Charpy-type notch cut in the back of the strip, down to the weld metal, made sure that only this was tested. Welding rods tested were '6012' and '6020.' Comparisons were made of the effect of filling the groove at one pass and with multiple passes. Impact tests at a range of temperatures from − 100° F. to 1800° F. were made. It was found that there was no great difference in the behaviour of these weld metals, or between the single bead and the multibead deposits. Though the impact values of single-bead deposits are lower, they follow the same trend, in relation to temperature, as the multibead. The '6020' deposits maintain their toughness down to 0° F. the transition to brittle fracture occurring between this temperature and − 50° F. The '6012' deposits demonstrate the transition at a point between room temperature and 0° F. J. P. S.

Strain Aging in Welding Low Carbon Structural Steel. W. H. Bruckner and W. E. Ellis. (Welding Journal, 1948, vol. 27, Sept., pp. 441-s–447-s). Tests of the effect of small amounts of strain followed by ageing have been made on a semikilled steel, on steel welded with 'E 6010' electrodes, and on the weld metal. A strain gradient was produced by drawing down a tapered bar to a cylindrical shape. It was found that where the cold work was less than 2%, there was no difference between the energy absorption, in the Charpy impact test, of as-strained and of strained and aged material, but with more than 2% cold work there was a significant reduction: this was even greater when the weld metal was annealed before straining and ageing.—J. P. S.

Experimental Study of the Weldability of Steels. B. J. Mouton. (Oerlikon Schweissmitteilungen, 1947, Jan.–Dec., pp. 99–132: [Abstract] Mécanique Documentation, 1948, vol. 3, Aug.–Sept., p. 2). An introductory report is given on studies and tests made on the weldability of steels. The process followed is described and results are presented graphically.

Results of Repeated Bend Tests as a Criterion of the Weldability of Sheets. (Circulaires de l'Institut Technique du Bâtiment et des Travaux Publiques, 1946, Série G, No. 14: [Abstract] Mécanique Documentation, 1948, vol. 3, Oct. p. 3).

Shrinkage Stresses in Spot Welded Joints. V. Hauk. (Welding Journal, 1948, vol. 27, Sept., pp. 453-s–456-s). This is a translation of a report from the Institute for Materials Research of the German Aircraft Experimental Laboratory, and deals with the use of X-ray back-reflection methods to determine shrinkage stresses on spot welds. By calculation, the stresses to be expected in (1) a spot weld on a single thickness, (2) a single spot weld between two sheets, and (3) six spot welds, in two rows of three, between two sheets were established. Good agreement between the experimental results and the theoretical calculation was found. J. P. S.

Low-Temperature Stress Relieving. T. W. Greene. (International Acetylene Association: Steel Processing, 1948, vol. 34, Sept., pp. 483–489). The results are presented of determinations of the residual stresses in butt-welded and fillet-welded steel plates. This enabled the necessary stress-relieving treatment to be specified. A description is given of the equipment and procedure adopted. It consists of a pair of oxy-acetylene burner heads followed by water-quenching sprays mounted on a moving carriage in such a way that two 6-in. bands, one on each side of the weld and extending from 2 to 8 in. from it, are heated to 350–400° F. and quenched by the water. This procedure has been successfully applied to welds in ships' hulls and pressure vessels.—R. A. R.

MACHINING AND MACHINABILITY

Basic Reasons for Good Machinability of "Free Machining" Steels. M. E. Merchant and N. Zlatin. (American Society for Metals, Oct., 1948, Preprint No. 21). A study has been made of the basic reasons for the improved machinability of steels due to the addition of sulphur, lead, or sodium sulphite, or to cold working. The effect of these four treatments on the coefficient of friction between chip and tool, mean shear strength of the metal in cutting, and machining constant of the metal, has been evaluated. High sulphur and lead both greatly reduced the coefficient of friction between chip and tool while shear strength was not reduced; all aspects of machinability benefited by their addition. Sodium sulphite did not appreciably change basic mechanical properties susceptible to direct measurement, and the free machining properties obtained were attributed to a less abrasive microstructure. Cold working produced a slight increase in the machining constant, a decrease in the strain hardenability and an increase in hardness.—J. C. R.

Tool Steel Dies Make their Mark on Machine Tool Details. (Machinist, 1948, vol. 92, Nov. 27, pp. 1004–1005). The use of hardened tool-steel relief-engraved marking dies, (made by Edward Pryor and Sons, Ltd.), for marking graduations on machine tools, such as micrometer dials, screw-cutting indicators, etc., is described.—R. F. F.

Roll Turning with Carbide Tools. F. R. Dinger. (Iron and

Steel Engineer, 1948, vol. 25, Sept., pp. 66–69). Illustrated descriptions are given of various carbide tools used for the roughing, finishing, and contour turning of rolls.—J. C. R.

Planing Cast Iron with Carbide Tools. G. J. Raible. (Machinery, vol. 73, Nov. 11, pp. 675–676). New planing tools, with clamped-on carbide tips, developed by Kenmetal Inc., for use on cast iron are described. These tools are suitable for deep cuts, coarse feeds, and interrupted cutting. Operating and maintenance conditions are discussed.—R. F. F.

Machines and Processes in the Production of Razor Blades. F. Kurek. (Zeitschrift des Vereines deutscher Ingenieure, 1948, vol. 90, Apr., pp. 125–128). An illustrated description is given of the sequence of processes and the automatic machines used for producing safety razor blades at Solingen. R. A. R.

Contribution to the Study of Grinding of Mechanical Parts. F. Eugène. (Machines et Métaux, 1948, vol. 32, Aug., pp. 273–280; Oct., pp. 345–354). Results of tests carried out on two steel specimens to study fine-grinding conditions are presented and discussed. Four abrasives were used: Calcined ferrous oxalate, alumina, chromium sesquioxide and kaolin. Duration of grinding, pressure on the metal sample, choice of abrasive, and effect of time and speed, were studied, as well as some properties of the grinders, such as the effect of the properties of the metal used, the effect of wear, resistance to embedding of abrasives, and a comparison of smooth and striated grinders.—R. F. F.

The Relationship between Machinability of Steels and Their Structure. (Pratique des Industries Mécaniques, 1948, vol. 31, July, pp. 229–232: [Abstract] Mécanique Documentation, 1948, vol. 3, Oct., p. 2). Several examples are given showing the relationship between the structure and machinability of American steels.

Notch Susceptibility to Cutting. N. N. Davidenkov and S. E. Belyaev. (Zavodskaya Laboratoriya, 1948, vol. 14, Aug., pp. 963–968). [In Russian]. The impact susceptibility to cutting of metals is considered in relation to the nature of the notch and the shape of the specimen. It is proposed to define the notch effect as the ratio of the difference between the yield strength of a notched and a smooth specimen to the yield strength of the smooth specimen. It is shown that this ratio can have either a positive or a negative value, and methods of determining its sign and magnitude are considered, the results of tests carried out on a number of steels and alloys subjected to various heat-treatments being discussed. A shape of specimen is proposed by the use of which the sign of the above ratio can be determined from the results of a single tensile test for longitudinal fracture.—S. K.

The Metallographic Evaluation of Surface Layers by the Flat Sectioning Technique. H. Klemm. (Metallwirtschaft, 1947, Nov., pp. 79–83). *See* Journ. I. and S.I., 1948, vol. 160, Nov., p. 328.

The Determination of Roughness by a Flat Section Procedure. H. Klemm. (Archiv für Metallkunde, 1948, vol. 2, Feb., pp. 46–49) The reproduction of a surface profile produced by the flat-section procedure previously described (*see* Journ. I. and S.I., 1948, vol. 160, Nov., p. 328) is explained. R. A. R.

CLEANING AND PICKLING

Electropolishing Stainless Steels. A. P. Schultze. (Steel, 1948, vol. 123, Nov. 15, pp. 109–114, 145–148). The methods and solutions for the electrolytic polishing of stainless steels are described, and the advantages of this finish are outlined. J. P. S.

Some Principles of Electrolytic Cleaning and Their Application to H.M. Ships. (Admiralty Corrosion Committee, Hull Corrosion Sub-Committee, ACSIL/ADM/48/771: [Abstract] Journal of the British Shipbuilding Research Association, 1948, vol. 3, Nov., pp. 517–518). Instructions are given for the cathodic cleaning and derusting of steel articles, using sea water as the electrolyte, on a scale suitable for service requirements. The present report is confined for the most part to the removal of rust in enclosed spaces. The factors involved in the design of anode systems and in assessing the electrical and time requirements are dealt with in detail and illustrated by theoretical examples.

The Principles and Scientific Applications of the Electrolytic Polishing of Metals. P. A. Jacquet. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 3–14). *See* Journ. I. and S.I., 1948, vol. 158, Feb., p. 284.

Technical Applications of Electrolytic Polishing. R. E. Halut. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 15–24). *See* Journ. I. and S.I., 1948, vol. 159, May, p. 97.

Some Special Applications of Electrolytic Polishing. H. C. J. de Decker, A. P. Krijff, and J. M. Pluut. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 25–32). *See* Journ. I. and S.I., 1948, vol. 158, Feb., p. 274.

Sheet and Tinplate Manufacture—The Pickling Process. J. H. Mort. (Iron and Steel, 1948, vol. 21, Sept., pp. 403–407; Oct., pp. 437–441; Nov., pp. 472–474). In the first part the author discusses the type, nature, and weight of scale formed on mild steel when the pack rolling process is adopted. The work of various investigators is reviewed and it is shown that the constitution of scale and the mechanism of oxidation are understood as is the effect of temperature, time, and certain oxidizing elements on the amount of scale formed. Formulæ are derived for the determination of the weight of scale per unit of area. Part two deals with the pickling of sheets and their treatment before annealing. Formulæ are given which facilitate the preparation of a pickling solution of any prescribed strength. The factors governing the rate of throughput are discussed. The last part deals with modern practice at sheet-mill pickling plants.—J. C. R.

Conditions in the Pickling Bath which Affect Hydrogen Embrittlement. C. A. Zapffe and M. Eleanor Haslem. (Wire and Wire Products, 1948, vol. 23, Sept., pp. 753–761, 792, 793). The factors affecting the hydrogen embrittlement of steel wire during acid pickling were investigated. The principal conclusions drawn were: (1) The highly ionized acids H_2SO_4, HCl, and HF, cause comparable embrittlement for comparable concentrations; (2) acids of lesser ionization, such as H_3PO_4 and CH_3COOH in particular, ionize so slightly that little or no embrittlement results; (3) all acids cause similar injury in the embrittling range of concentrations; (4) at very high concentrations, H_2SO_4 and CH_3COOH ionize so slightly that little or no embrittlement is caused; (5) increasing the temperature of the pickling bath increases hydrogen embrittlement; (6) sulphur, which may enter the bath through the leaching of high-sulphur steels aggravates embrittlement; (7) arsenic in small quantities also aggravates embrittlement, but with larger concentrations in the acid pickling bath it effectively inhibits hydrogen embrittlement; and (8) quinoline ethiodide behaves like arsenic but is more expensive.—R. A. R.

Chemical Pickling in the United States. A. Mangin. (Chimie et Industrie, 1948, vol. 60, Oct., pp. 331–335). American practice for the chemical pickling of ferrous metals is discussed and some typical baths are described.—R. F. F.

"Nitralising." A Pre-Enamelling Treatment for Steel Sheets. T. Gilbertson and R. Robinson. (Sheet Metal Industries, 1948, vol. 25, Nov., pp. 2238–2240). The necessity for enamelling steel which is not of the proper enamelling grade has led to faulty coatings by blister and copperhead formation. A method of preventing this is described. It consists of degreasing and acid-pickling the metal and then immersing it in fused sodium nitrate at a temperature of about 500° C. This is called "Nitralising."—R. A. R.

Electrostatic Descaling for High-Speed Production. A. P. Schulze. (Production Engineering and Management, 1948, vol. 22, Sept., pp. 67–71: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 18). The author describes the use of the Bullard-Dunn process for scale and oxide removal from ferrous parts on a volume production basis.

Barrel Finishing of Metal Products. Part 25—Factors in the Barrel Finishing of Stainless Steels. H. L. Beaver. (Products Finishing, 1948, vol. 13, Oct., pp. 40–52). General information on the barrel finishing of stainless steel is given. Good results are obtained with heavy loads (800 to 1000 lb.) in the barrel.—R. A. R.

PROTECTIVE COATINGS

Mass Production Techniques in Plating Steel Auto Parts. (Iron Age, 1948, vol. 162, Nov. 18, pp. 106–108). At the Syracuse, N.Y., plant of Brown-Lipe-Chapin Division of General Motors Corp. electroplating and polishing of bumper guards and other steel fittings is fully mechanized. Parts

are plated with chromium-on-nickel-on-copper, with intermediate dippings and rinsings, in a total of twenty-four automatic operations.—J. P. S.

Protective Metal Finishes for Radio and Electrical Equipment. A. G. Sussex. (Commonwealth of Australia, Department of Supply and Development, Munitions Supply Laboratories, Mar., 1948, Circular No. 9 : [Abstract] Bulletin of the British Non-Ferrous Metals Research Association, 1948, Nov., p. 357). This circular was compiled as a general guide in the selection and use of electroplated and chemical surface finishes for the protection of radio equipment in tropical areas. There are sections on the general nature of the problem and on the protection of steel and of the non-ferrous alloys. A list of relevant British, American, and Australian specifications is provided.

Electroplating Alloys from Cyanide Baths. J. B. Mohler. (Iron Age, 1948, vol. 162, Nov. 25, pp. 84–88). The plating of alloys such as brass, bronze, speculum metal, and tin-lead alloys is discussed, and some of the factors for satisfactory operation of alkaline cyanide baths are established.—J. P. S.

The Harmful Effect of Films of Powdered Substances on the Adherence of Electrolytic Deposits. J. Liger. (Galvano, 1945, vol. 14, Oct., pp. 7–9). When the composition of a plating bath is not carefully controlled, or the rinsing after pickling has been inadequate, particles of metals or impurities may be suspended in the electrolyte and adhere to the article being plated with deleterious effects on the plating process. Methods of preventing this are discussed.

German Electroplating Practice. A. W. Wallbank. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 83–90). This paper reviews the principal features of German electroplating practice as reported in British Intelligence Objectives Subcommittee Reports 429, 643, and 1615.—R. A. R.

The Mechanism of Exfoliation of Electrodeposited Surfaces. A. T. Steer. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 165–177). Investigations of the reactions of metal surfaces to various physical and chemical treatments are reported and their influence on the exfoliation of electrodeposited coatings is examined. Three main types of exfoliation ; those due to stress, chemical or corrosive action, and a combination of stress and corrosion, are noted, and micrographs at 2500 diameters illustrate examples of each type. The importance of etching of the layer of stressed metal before plating is emphasized. A well-controlled etch will limit pitting to a depth of 0·00002 in., and such treatment will ensure a stable plate.—R. A. R.

Porous Chrome Plating of Cylinder Bores by the Van der Horst Method. C. D. B. Williams. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 99–101). The Van der Horst method of chromium plating to produce an oil-retaining surface on cylinder walls of internal combustion engines is described. The coating is produced chiefly by a post-plating etch carried out by reversing the current. This causes the whole surface to be broken into a network of visible cracks with plateaux between them.—R. A. R.

The Structure of Thick Chromium Electrodeposits. J. J. Dale. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 185–194). The paper describes : (*a*) Investigations of the microstructure of electrodeposited chromium, its relation to plating conditions, and its connection with the channel network produced by surface etching ; (*b*) experiments on the effect of heating on the microstructure ; and (*c*) attempts to identify the minor constituents in the structure by analytical methods. The channel network is refined by : (1) Lowering the bath temperature ; (2) decreasing the sulphate ratio ; and (3) at above 55° C. increasing the current density, at below 55° C. decreasing the current density. The chromic acid content appears to have only a minor effect.

R. A. R.

Mechanical Properties of Nickel Deposits. E. J. Roehl. (Monthly Review of the American Electroplaters' Society, 1947, vol. 34, Oct., pp. 1129–1140 ; Plating, 1948, vol. 35, May, pp. 452–455, 478). An investigation of the effect of the plating conditions on the mechanical properties of nickel deposits is reported. The highest ductility (37·3% in 1 in.) was obtained with a Watts solution at *p*H 4·5 ; annealing the deposit for 15 min. at 1400° F. raised the ductility to 54·6%. Prolonging the anneal at 1400° F. reduced the ductility. Annealing for 15 min. at 1400° F. raised the elongation of all deposits to 50% independent of *p*H, current density, and temperature and composition of Watts and all-chloride baths. The hardness and tensile strength of as-plated deposits decreased with increase in bath temperature, the effect being more pronouced at low than at high *p*H. The second part deals with the effect of changes in the *p*H value on the properties of deposits obtained in standard, in low-chloride, and in low-boric-acid baths.—R. A. R.

Heavy Nickel Deposition as a Manufacturing Operation. S. Vernick and F. Willetts. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 113–120 : Metal Finishing, 1948, vol. 46, Nov., pp. 76–81). A process for depositing a heavy nickel coating, free from nodules and capable of being readily ground to size, on a cast-iron base is described. After cleaning operations involving degreasing, alkali cleaning, and electrolytic etching, plating is carried out in an electrolyte containing nickel sulphate 40 oz., nickel chloride 3 oz., and boric acid 4 oz. (all per gallon), at a *p*H of 5·7, with a current density of 5 amp./sq. ft. for 15 min. to bring the solution to temperature, and then at 25 amp./sq. ft. for 500 min. Very close chemical and physical control of the processes is necessary, and a special grinding technique is required.—R. A. R.

The Brightening Action of Organic Sulphonates in Bright Nickel Plating. G. E. Gardam. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 203–207). The mechanism by which organic sulphonates added to a nickel-plating bath brighten the coating has been studied. There are three possible ways in which sulphonate might enter the deposit—adsorption on nickel hydroxide, adsorption on metallic nickel, and discharge of a complex cation. Evidence in support of the first has been obtained. The brightening is ascribed to the smoothing action brought about by inclusion of a greater amount of sulphonate on the raised areas of the cathode ; the production of a fine grain is incidental to brightening and is not its main cause.—R. A. R.

Determination of Impurities in Electroplating Solutions. VIII. Traces of Cadmium in Nickel Plating Baths. (Plating, 1948, vol. 35, May, pp. 458–462). Copper and iron are removed by precipitation with cupferron and extraction of the cupferrides with amyl acetate. Cadmium is separated from the nickel by precipitation with 2-mercaptobenzole-thiazole in an ammoniacal solution with chloroform. The cadmium is returned to an aqueous medium by shaking the chloroform extract with 6 *N* HCl. The solution is made strongly alkaline with NaOH and the cadmium extracted with a carbon tetrachloride solution of dithizone. After dilution to 50 c.c., the extinction of the coloured system is measured using light with a wavelength of about 520 millimicrons or a suitable filter.—R. A. R.

Galvanizing Conveyor Frames. (Bulletin of the American Hot Dip Galvanizers Association, Inc., 1948, Aug., pp. 2–3 : Z.D.A. Abstracts, 1948, vol. 6, Nov., pp. 163–164). A modern hot-dip galvanizing plant is described with a bath 40 in. by 42 in. by 12 ft. It has a capacity of 30 tons of zinc and, using a conveyor belt, can galvanize 3500 lb./hr. The bath is gas-fired with a baffle ensuring a uniform heat flow to the top. Dross is kept to a minimum and temperature can be closely controlled. Prefluxing is used.

Chemical Treatments for Zinc Surfaces—A Review. H. A. Holden. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 57–70). *See* Journ. I. and S.I., 1948 : vol. 158, Feb., p. 276.

Mechanization of Galvanizing Processes. N. J. Dokin. (Vestnik Ingenierov Techniko, 1948, Mar.–Apr., pp. 60–66 [in Russian] : [Abstract] Mécanique Documentation, 1948, vol. 3, Oct., p. 6). The author discusses various installations set up by the technical department of Metallochinzaschtita with a view to mechanizing galvanizing processes.

Split Type Electric Furnace for Galvanising Baths. W. G. Imhoff. (Iron Age, 1948, vol. 162, Nov. 11, pp. 114–115). Sectional and ring-type furnaces have been developed in Australia to permit easy access to the galvanizing kettle for repairs. The ring-type furnace lifts up from the kettle, while

the sectional type, for rectangular kettles, can be moved away piece by piece as required.—J. P. S.

Chemical Stability of Tin Coatings. N. N. Gratsianskii and P. F. Kalynzhnaya. (Journal of Applied Chemistry, U.S.S.R., 1948, vol. 21, Apr., pp. 341–346 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 20). Physical and chemical characteristics of electroplated tin coatings from various baths, especially stannate and sulphuric acid, were studied, and factors influencing their chemical stability are indicated.

An Examination of the Thiocyanate Porosity Test for Tinplate. J. Pearson and W. Bullough. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 376–380) The thiocyanate porosity test for tinplate has been found to require modification. Suggestions are made in respect of the preparation of the test solutions, the cleaning of the tinplate specimens, and the estimation of dissolved iron, and results are presented to indicate that the method is then suitable for providing a quantitative estimate of the extent of discontinuities in the tin coating on commercial hot-dipped tinplate.

Operational Formulas for Electrotinning Steel Strip. J. H. Mort. (Iron Age, 1948, vol. 162, Dec. 2, pp. 104–110). The calculations relating the rate of deposition of tin, in continuous acid plating of strip, to current density, immersion time, speed of strip, and current efficiency are explained. Two simple slide rules and two nomographs are described, whereby the calculations may be made more quickly.—J. P. S.

Surface Defects on Hot-Dipped Tinplate. T. Fielding. (Tin Printer and Box Maker, 1948, vol. 24, June, pp. 10, 12–13). The author discusses the causes of such surface defects as greyness, mottle, blisters, 'crocodile,' grease 'saucers,' and porosity.—J. C. R.

Electrolizing Prolongs Tool Life and Protects Wear Parts. (Tool and Die Journal, 1948, vol. 14, Aug., p. 56 : [Abstract] Metals Review, 1948, vol. 21, Sept., p. 24). An account is given of a new process said greatly to prolong the life of cutting tools, dies, gauges, and wear parts. It involves a high-frequency treatment which raises the fatigue limit of the tools, and a process of evaporation and condensation by which a 0·00003 to 0·00005 in. layer of a new hard alloy is deposited on the cutting edges or working surfaces.

The Effect of Operating Conditions on the Throwing Power of Cyanide Cadmium Plating Solutions. P. Baeyens. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 109–112). Experiments are reported the object of which was to determine how the throwing power of cyanide cadmium plating solutions was affected by changes in bath temperature and current density. For a given average current density the throwing power decreases with increase in temperature. At a constant temperature the throwing power increases with rising average current density. To keep constant throwing power with rising temperature the average current density must be increased. R. A. R.

The Electrodeposition of Tungsten Alloys Containing Iron, Nickel, and Cobalt. A. Brenner, Polly Burhead, and Emma Seegmiller. (Electrodepositors' Technical Society, Third International Conference on Electrodeposition, Sept. 17–20, 1947, pp. 131–146). Methods are described for electrodepositing alloys of tungsten with iron, cobalt, or nickel. The plating solutions consist essentially of the appropriate metal salts together with salts of certain hydroxyorganic acids in ammoniacal solutions at a *p*H of about 8·5. Deposits as thick as several hundredths of an inch can be made with good current efficiency. Data on the thermal, mechanical, electrical, and chemical properties are presented.—R. A. R.

New Anti-Corrosion Lacquer. I. V. Vodzinskii. (Stanki i Instrument, 1948, Feb., p. 25 [in Russian]: [Abstract] Mécanique Documentation, 1948, vol. 3, July, p. 3). Details are given of a new lacquer for protecting machine tools against corrosion during transit. The composition as given by the Gorki works is : Nitrocellulose 35% by weight, camphor 20%, drying oil 5%, acetone 40%. Parts protected by this lacquer showed no trace of corrosion after two weeks in an acid or basic atmosphere.

Drying and Baking of Synthetic Varnishes by Induction Heating. G. Génin. (Peintures, Pigments, Vernis, 1948, vol. 24, Nov., pp. 344–349). The applications of induction heating to the drying and baking of synthetic varnishes used for protection of metals against corrosion, are discussed.

Rehabilitation of Existing Pipelines. A. B. Anderson. (Iron and Steel Engineer, 1948, vol. 25, Sept., pp. 57–59). A process is described for cleaning and coating water pipelines. First the pipe must be thoroughly cleaned and freed from all rust and other deposits, and to accomplish this a new sectional cleaning machine has been designed. Ploughs, scrapers, and wire brushes under high pressure break away the deposits, dig out the pitting, and brush the interior of the pipe in one operation. A specially prepared bitumen compound is then electrolytically deposited from an aqueous solution on the interior of the pipe. The process reduces pumping costs and avoids replacement of the pipeline.—J. C. R.

Principles of Protecting Metals with Organic Coatings. A. J. Eickhoff and W. E. Shaw. (Corrosion, 1948, vol. 4, Oct., pp. 463–475). After briefly reviewing the theories relating to corrosion, the manner in which various methods of surface preparation affect the adhesion of paint is discussed and recommendations on paint schemes for steel to resist different forms of attack are made.—R. A. R.

Weathering Tests on Paints. W. H. Droste. (Archiv für Technisches Messen, 1948, April, No. 154 : Electrical Engineering Abstracts, 1948, vol. 51, Dec., p. 305). Each type of paint is applied to the appropriate background, *e.g.*, anti-rust paints to iron, aeroplane paints to light alloys, wood paints to fir panels, and house paints to stone or mortar. Long-term weathering tests are carried out with plates facing south and directed upwards at an angle of 45°. Laboratory tests are carried out for (*a*) light exposure to artificial sunlight lamps ; (*b*) exposure to water, rain, and steam ; (*c*) heating to 50–60° C. ; (*d*) cold ; (*e*) oxygen ; and (*f*) corrosive gases for special paints, *e.g.*, smoke for railway station paints. Evaluation of test results is carried out on the DIN "rust scale" having five degrees of severity corresponding to the destruction of 10%, 20%, 30%, 40%, and 50% of the painted area. When degree 3 is reached the paint should be renewed.

Methods of Testing the Protective Properties of Anti-Corrosion Coatings of Steel under Conditions of Variable Stress. A. N. Mitinkskii and E. S. Reinberg. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1247–1250). [In Russian]. Some machines suitable for the testing of the effects of various anti-corrosion coatings on the resistance to breaking of steel specimens under variable stress conditions are described, and data relating to three types of coating for protection from sea water are presented.—S. K.

The Rôle of Paint in Combating Corrosion in the Petroleum Industry. P. L. Lotz. (American Petroleum Institute, Thirteenth Mid-Year Meeting, May 10–13, 1948, pp. 19–21). The characteristics of priming and top coats of paint are explained, and the properties and particular applications of plastic paints based on chlorinated rubber systems, vinyl systems, vinyl-resin/latex dispersion systems, and styrene systems are outlined.—R. A. R.

Paint in Civil Engineering. R. Hammond. (Paint and Paint Manufacture, 1948, vol. 18, Oct., pp. 343–346 : Z.D.A. Abstracts, 1948, vol. 6, Nov., p. 166). The causes of rusting and the methods of combating it are explained. The paint systems discussed are those based on lead pigments. There is, however, a short account of metal coatings, and zinc showed up favourably in these tests. The preparation suggested for galvanized steel that is to be painted, is a degreasing dip in an acid-containing solution. The author is interested in the protection of iron and steel structures, and examples of failure and successful protection of these structures are given.

The Mechanism of Action of Metal Protective Paints. A. C. Elm. (Paint, Oil, and Chemical Review, 1948, vol. 111, Aug. 19, pp. 16–38 : Z.D.A. Abstracts, 1948, vol. 6, Nov., p. 166). The author reviews the data relating to the protective value of metal-pigmented paints. Red lead, chromates, and metal-powder pigments are examined and suggestions made as to their mode of action. The function of these paints as moisture carriers is considered, a table of the comparative permeability factors being given. Moisture impedance is not the controlling factor in the protective value of a paint ; the solution of the problem is probably to be sought in the electrochemical behaviour of the moisture permeating through the barrier films.

How to Paint the Product. H. E. Linsley. (Machinist, 1948, vol. 92, No. 13, pp. 941–956 ; Nov. 27, pp. 1007–1018). Methods of preparing and cleaning the surface of iron and steel, galvanized sheets, terne-plates, and non-ferrous metals,

the selection of suitable paints, and methods of painting and drying are discussed.—R. F. F.

Pre-Treatments for Galvanized Iron Prior to Painting. R. Mansell. (Organic Finishing, 1948, vol. 9, Aug., pp. 38–40: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 20). Various methods are discussed including weathering, mechanical sanding, blasting and wire brushing, acid etching, plating, and deposition of inorganic films such as sodium silicate.

The Use of Antirust Paint against the Corrosion of Structural Metalwork. P. Pessi. (Hommes et Techniques, 1948, July–Aug., pp. 37–39 : [Abstract] Mécanique Documentation, 1948, vol. 3, Oct., p. 6). A description is given of studies made by the Office Technique pour l'Utilisation de l'Acier to improve the protection against corrosion of present-day commercial steels.

High-Speed Rotor Tests of Paints for Under-Water Service. F. Wormwell, T. J. Nurse, and H. C. K. Ison. (Journal of The Iron and Steel Institute, 1948, vol. 160, Nov., pp. 247–260). Part I describes apparatus developed at Chemical Research Laboratory for investigating the corrosion of metals exposed to water or aqueous solutions under conditions of rapid movement (comparable with ships' speeds). An ebonite holder carrying suitably prepared metal specimens is rotated at a controlled speed, the nature and amount of corrosion after varying periods of test being estimated by measurements of weight-loss and depth of corrosion penetration, supplemented by visual examination. The apparatus lends itself to modifications for testing specimens of different forms, for example, rings cut from tubing or portions of wire cable.

Part II deals with the use of the rotor apparatus in testing a series of typical ships'-bottom compositions. These were applied as three-coat systems to the small rotor specimens by use of a special jig, the amount of paint being controlled and measured. Tests were conducted in artificial sea water (similar in composition and *p*H to natural sea water) at speeds of the order of 20 knots for periods up to 50 days. The condition of the paint on each specimen was appraised visually each day ; finally weight-loss measurements were made on selected 50-day specimens. The final qualitative and quantitative results showed good correlation with those obtained in raft tests of the same compositions carried out by Dr. J. C. Hudson. The compositions' order of merit in respect of protection against corrosion was very similar in the two series of tests, but the rotor tests gave results in much shorter periods. It was concluded that the rotor test affords a rapid and convenient method of assessing the value of paint systems intended for use on submerged metals.

Parts III and IV describe the use of the apparatus in comparing the merits of several paints formulated by Fancutt and Hudson. Although the order of merit was not identical in all respects, in the laboratory and raft tests, paint No. 32 (pigmented with white lead, basic lead sulphate, and Burntisland red in a modified phenol-formaldehyde resin–oil medium) showed outstanding superiority in both series. The influence of modifications in the medium of paint No. 173 (based on No. 32) was studied in a further series of tests : some differences were observed, although all the paints showed good adhesion.

Experimental results are given in Part V, showing the acceleration of paint failure and of corrosion of the underlying steel caused by an increase in rate of movement, or by a rise in temperature of the artificial sea water. Part VI deals with methods of assessment of paint failure in rotor tests. Measurements of depth of penetration of corrosion are given for selected paint systems and the results are discussed in relation to the estimates of " useful life " of a paint based on the test-period required to produce loss of adhesion over 10 per cent. of the specimen area. The mechanism of blistering, and of paint failure generally, is discussed in relation to the results obtained from tests in sea water and (for a few paints) in fresh waters.

The results as a whole indicate that many paints are now available which adhere so well, even in conditions of rapid movement that more intensive test conditions are required to evaluate the paints in reasonably short periods. A combination of more intensive conditions of test with more sensitive (electrochemical) methods for detecting paint failure should lead to further advances.

POWDER METALLURGY

Current Trends in Powder Metallurgy. W. F. Toerge. (Steel, 1948, vol. 123, Nov. 22, pp. 73–78, 80, 111–112). The present position of powder metallurgy is described ; mixing, pressing, die materials, sintering, and the preparation and classification of powders are all covered.—J. F. S.

Industrial Applications of Powder Metallurgy. R. Girschig. (Métallurgie, 1948, vol. 80, Nov., pp. 33–35, 37, 39). The author surveys production methods and properties of metal powders, their moulding and sintering, the mechanical properties of sintered parts, and the fields of application of powder metallurgy.—J. C. R.

Metal Powders. G. L. Miller. (Canadian Metals and Metallurgical Industries, 1948, vol. 11, Oct., pp. 18–22, 44, 46). The following methods of producing metal powders are surveyed : Milling, machining, atomization, granulation or shotting, graining, reduction of metallic oxides, reduction of metallic salts, electrolysis, carbonyl processes, and hydride processes.—R. A. R.

Compacting of Iron Powders. (Iron Age, 1948, vol. 162, Nov. 25, pp. 96–98). This is an English summary of an article by F. Eisenkolb which appeared in Stahl und Eisen,1947, vol. 66–67, Feb. 27, p. 78. *See* Journ. I. and S.I., 1947, vol. 156, June, p. 314.

The Moulding and Sintering of Metal Powders. G. Blanc. (Fonderie, 1948, Jan., pp. 1007–1021). The author first deals with mechanical processes of moulding metal powders such as the Hametag method, atomization processes such as the D.P.G. (Deutsche Pulvermetallurgische Gesellschaft) method, chemical processes such as the RZ method, and electrolytic processes. The characteristics of metal powders are reviewed and the moulding, pressing, and sintering operations are briefly described. Finally the properties of iron-base and copper-base sintered powders are examined and their applications are discussed. A bibliography of twenty-seven references is appended.—J. C. R.

Contribution to the Theory of Sintering. P. Schwarzkopf. (First International Powder Metallurgy Conference, Graz, July, 1948 : Powder Metallurgy Bulletin, 1948, vol. 3, Sept. pp. 74–87). After dealing with the relationship between recrystallization and sintering and the forces responsible for sintering, three stages of bonding are described and discussed, namely, the formation of ' point ' bonds between adjacent particles, the lateral growth of these bonds, and the disappearance of disconnected pores. In all three stages plastic flow plays a determining part, and in the first two surface diffusion is an important contributing factor ; plastic flow and surface diffusion do not take place independently R. A. R.

Shrinkage and Growth in the Sintering of Metals. K. May. (Archiv für Metallkunde, 1948, vol. 2, No. 5, pp. 154–163). Investigations of the factors affecting volume changes in the process of powder metallurgy are reported. Reducing the grain-size of the compact increases the shrinkage. The reduction of the oxide coating during sintering contributes to the shrinkage. The shrinkage decreases with increasing pressure in such a manner that the ratio of the increase in density (due to sintering) to the pore volume in the pressed state is a constant which is independent of the pressure. In a limited temperature range just above the A_3 temperature the mobility of the iron atoms is less than at temperatures just below A_3 and there is therefore no increase in density when the temperature is raised in this range above A_3. If one component of a binary compact takes up more of the second component by diffusion than the second one receives from the first, the first grows by a measurable amount which can be calculated when the diffusion conditions are known. An investigation of a 50/50 iron–nickel compact showed that the diffusion in each direction was practically the same so that the growth was small.—R. A. R.

Powdered-Metal Friction Material. F. J. Lowey. (Mechanical Engineering, 1948, vol. 70, Nov., pp. 869–875). Powdered-metal friction material is composed of a sintered mixture of powdered metals, usually copper, iron, lead, and tin, and non-metals, usually graphite and silica. Generally it is classified as copper or iron-base mix depending on which is the predominant constituent. The sintered product is bonded directly to a core or backing plate, usually low-carbon steel, which takes most of the mechanical stress required of the friction element. The author describes the manufacture of parts using this material, with a survey of the purposes for which it can be used.—J. C. R.

Kinetics of Sintering Compacted Iron Powder. G. F. Hüttig. (Metal Treatment and Drop Forging, 1948, vol. 15, Autumn Issue, pp. 155–158). The author considers the results of Bernstorff on time and temperature effects in sintering (*see* Journ. I. and S.I., 1948, vol. 160, Nov., p. 331). from the thermodynamic point of view. He derives an equation from Arrhenius' law and states that, where τ is the time for the sintering process, T the absolute temperature at which sintering is carried out, q an empirical value related to the heat of activation, expressed in calories and called "the temperature increment,"

$$-\log \tau = \frac{-q}{2{\cdot}303 \times 1{\cdot}985} \times \frac{1}{T} + C.$$

The validity of this is checked by experimental values relating to transitions from the same initial state (*i.e.*, non-heated compressed powder) to the same final state, that in which a specific property, *e.g.*, tensile strength, always attains the same value. Conformity with the equation is found to be generally applicable in the ranges of higher temperature and longer periods of reaction; for shorter times and at lower temperatures conformity is lacking because a number of intermediate stages of sintering are traversed each with its own reaction mechanism and lower heat of activation.—J. P. S.

PROPERTIES AND TESTS

New Methods of Calculating Strength. E. Siebel. (Zeitschrift des Vereines deutscher Ingenieure, 1948, vol. 90, May, pp. 135–139). When parts of steel structures are subjected to non-uniform loading, data from static tests do not provide the correct basis for design calculations. It is suggested that for static non-uniform loads the 0·2% proof stress for the position of maximum stress should be the basis, whilst for dynamic loads the basis should be the fatigue strength associated with the derived reduction in stress at the position of maximum stress.—R. A. R.

The Calculation of Limits of Deformation. E. Siebel and S. Schwaigerer. (Zeitschrift des Vereines deutscher Ingenieure, 1948, vol. 90, Nov., pp. 335–341). The determination by calculation and by graphical methods of the deformation limits under conditions of non-uniform load are explained for the common case of triaxial loading, assuming that the elasticity theory of elongation distribution is also valid for deformation above the elastic range. These methods are applied to the case of a rotating hollow cylinder.—R. A. R.

A New Theory of Elasticity and Strength. H. Brandenberger. (Seventh International Congress of Applied Mechanics, London, Sept. 1948: [Abstract] Journal of the British Shipbuilding Research Association, 1948, vol. 3, Nov., p. 490). The current theory of elasticity determines the external stresses acting in the various surface planes of a body in equilibrium, and assumes that the internal forces are equal to them. The author shows how the conception that the stresses and strains may be considered to consist of two parts, those involved in a change in volume and those involved in distortion, makes it possible to determine the relationship between stress and strain, based on their physical interdependence. The lateral contraction under a simple tension load can thus be explained by the existence of two load stresses, the volume-change stress and the distortion stress, acting in the lateral direction. Although they are equal in magnitude the moduli of elasticity controlling their behaviour are different, and they therefore cause a deformation. Because of this two-fold elastic behaviour of a solid, it will offer a resistance to a change in volume, which can be called "space stress" and a second resistance, to a change in dimensions, or to distortion, which may be called "network stress," to indicate that a lattice-like structure is visualized. This new conception is used to explain the lateral contraction which accompanies a simple longitudinal tension. Complete elasticity is assumed for the space stress, the solid body, when free from stress, always trying to regain its original volume. In the case of the network stress, however, a limit is imposed because, when the stress or strain exceeds a certain value, a permanent set occurs which is known as yielding. Since the body is not loaded equally in all three principal stress directions, the body will first yield only in that direction in which the network stress has reached its maximum value, and one-sided yielding occurs. A permanent deformation will also occur in the lateral direction in which no yielding has taken place. Complete yielding does not set in until the network stress resistance force in the lateral directions likewise reaches its maximum permissible value. It is necessary to distinguish between the first and second yield points. It is now possible to calculate the elastic limit easily from the second yield limit, which can be easily determined. The hysteresis loop for any load can also be calculated. The reversed stress limit obtained in endurance tests coincides with the new elastic limit, and the endurance limit coincides with the yield limit for the material. Elastic measurements on test samples can only give a completely true picture when the samples have been annealed after their mechanical production, since strain-hardening of the outer surfaces is caused by the cutting processes involved. Using the new theory of space and network stresses the maximum network stress can be determined from any kind of strength test, such as a simple tension test. The stress corresponding to the first and second yield points can then be calculated as well as the consequent permanent sets for all conditions of loading, whether along one, two or three axes, or whether the load is steady or changed repeatedly.

Apparatus for the Mechanical Testing of Locomotive and Other Piston Rings. P. G. Korolev. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., p. 1271. [In Russian]. A simple apparatus is described by which the magnitudes of the elastic and residual deformation of a ring under concentrated stresses can be determined.—S. K.

A Horizontal Machine for Testing Materials. S. E. Khanin. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1269–1271). [In Russian]. The advantages of horizontal machines for the mechanical testing of materials are discussed and a description is given of a machine of this type and of its use. S. K.

Transverse Mechanical Properties in Heat Treated Wrought Steel Products. C. Wells and R. F. Mehl. (American Society for Metals, Oct. 1948, Preprint No. 23). Studies have been made of the effect on transverse ductility of size of ingot, forging reduction, yield strength, reheating treatment and non-metallic inclusions. The steel used contained 0·30–0·45% carbon and 1·5–4·5% alloying elements and was in the form of tapered solid forgings or tubes and varied from a minimum of 2·5–5·5 in. outside dia. and 85 in. long to a maximum of 17–25 in. outside dia., 8·5 in. inside dia., and 340 in. long. Relations between transverse reduction of area and transverse impact, and between transverse impact and yield strength have been determined and also the relation of angle between longitudinal axis and flow-line direction in specimens, to the mechanical properties. The significance of angular fracture and of porosity resulting from deep acid etching in relation to transverse reduction-of-area behaviour is discussed and evaluated.—J. C. R.

How to Determine the Yield Point in Bending and Torsion. N. N. Davidenkov. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1233–1237). [In Russian]. Theoretical consideration is given to the determination of yield point in the processes of bending and torsion. Two yield points, the real and the nominal, must be recognized; the first is based on the calculation of the true strains, whilst the second is deduced from the calculation of strain by methods applicable to elastic media. The relevant formulæ are presented, and a method is proposed for the exact calculation of the influence of the residual stresses by graphical means. Consideration is given to the conditions existing in steels of high toughness.—S. K.

The Determination of the Conventional Yield Point for High-Endurance Steels Rolled into Sheet. G. G. Vasilev. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., p. 1272). [In Russian]. A brief description is given of modifications carried out on an Amsler-type machine to enable the yield point of steels which do not normally display a physical yield point to be determined.—S. K.

Significance of Proportional Limit and Yield Strength. J. L. Everhart. (Iron Age, 1948, vol. 162, Dec. 2, pp. 111–113). The difficulty of determining the true limit of proportionality of a metal is described, and the value of reporting yield strength, obtained at various offsets, such as 0·01% or 0·02% is recognized. It is desirable that it should always be made clear whether the figures given refer to offset or permanent set.—J. P. S.

Bend-Tests on Peripherally Supported Discs. Ya. B. Fridman and I. M. Roitman. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1238–1240). [In Russian]. The use of

peripherally supported discs 3 mm. thick and 58 mm. in dia. for bend tests is described, and results obtained thereby for specimens of a steel subjected to tempering at up to 600° C. are presented together with the corresponding results obtained when the specimens were in the form of 50 × 50 mm. plates of the same thickness.—S. K.

Residual Stresses and Microstructure in Hollow Cylinders. H. B. Wishart and R. K. Potter. (American Society for Metals, Oct. 1948, Preprint No. 24). The authors have set up compressive stresses at the surface of hollow steel cylinders (7 in. dia.) by quenching the cylinders from an austenitizing temperature. Steels containing 0·46%, 0·33%, and 0·20% carbon were used for these experiments. Data derived from experiments showed that: Cylinders quenched with plugged ends developed a tensile stress at the bore whilst a compressive stress formed when the cylinder was quenched with open ends; appreciable amounts of tempered martensite formed at the surface after quenching in water, but not after quenching in oil; no direct relationship exists between changes in hardness and residual stresses, compressive stresses at or near the surface of the cylinders were, in general, lowered with decreasing carbon content where not influenced by the tempered martensite factor.—J. C. R.

Determination of Tangential Strains in Plastically Twisted Round Rods and Tubes. N. F. Lashko. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1251–1254). [In Russian]. Equations for the peripheral strains in plastically twisted bars or tubes are considered and deformation diagrams for various types of steel and some non-ferrous metals are given. S. K.

Photoelastic Investigation of the Stress Concentration Caused by Surface Irregularities. A. F. C. Brown and V. M. Hickson. (Seventh International Congress of Applied Mechanics, London, Sept., 1948 : [Abstract] Journal of the British Shipbuilding Research Association, 1948, vol. 3, Nov., p. 494). A photoelastic investigation has been made of the stress concentrations set up at the base of the grooves left by machining operations. Surface roughness records were made on samples of heat-treated alloy steel, finished by fine-grinding and fine-turning, and it was considered that the cross-sections of all the grooves in the surface could be represented by circular arcs. The ratio of depth to radius of the grooves was measured, and a series of double-notched specimens was tested under tension, the grooves being represented on a much enlarged scale by the notches, which were circular arcs of different radii and depth. Photoelastic tests were made on these shapes in plane stress. The material used was polymethyl methacrylate, since the determination of the stress concentration was found to be less vitiated by edge effects than would have been the case with materials of higher photoelastic sensitivity. Accurate measurement of small fractions of a fringe was made possible by the use of a photometric method. The results indicate that considerable stress concentration are set up at the surface of the material by the irregularities present in a machined finish. These stress-concentration factors can be expected to operate in static loading and to be approached in fully quenched or case-hardened steel. Under repeated loading, unless there is continuous plastic deformation at the root of a notch, the material at this point must be subjected to the mean range of stress multiplied by the full stress-concentration factor.

The Fracture of Mild Steel Plate. C. F. Elam Tipper. (Admiralty Ship Welding Committee, 1948, Report No. R.3: H.M. Stationery Office). *See* Journ. I. and S.I., 1947, vol. 157, Oct., p. 300.

The Deformed Region. Ya. B. Fridman and A. A. Bat. (Zavodskaya Laboratoriya, 1948, vol. 14, Sept., pp. 1124–1130). [In Russian]. The convention adopted in the presentation of the results of testing for toughness is criticized on the ground that deformation is confined to a comparatively small zone of the specimen, and an account is given of the experimental study of the deformed region in specimens of steels of medium and high toughness and of some alloys. Two methods were used; in the first, the specimen was coated with a brittle lacquer which cracked according to the nature of the deformation; in the second, the specimen was highly polished, the deformations produced in the polished surface being visible. Both static and dynamic testing methods were used, the respective results being compared and discussed.—S. K.

Fatigue in Metals. A Critical Survey of Recent Research and Theories. P. Feltham. (Iron and Steel, 1948, vol. 21, Oct. pp. 431–436). The most salient features of fatigue are surveyed in the light of experimental research work and recent theories. A bibliography of eighty references is appended.—J. C. R.

A Contribution on the Question of Increasing the Fatigue Limit by Surface Cold-Working. S. I. Ratner and I. I. Zakharov. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1241–1246). [In Russian]. Experiments are described in which the increase in the fatigue limit as a result of various types of surface treatment was determined for specimens of a chromium–manganese–silicon steel, the effects on this increase of varying contents of carbon and silicon also being measured. The results are discussed, and it is concluded that one of the main reasons for increased fatigue limit is the enhanced resistance to rupture acquired by the outer layers of the specimen during the cold-working process, the surface microgeometry also being improved thereby. It is also stated that residual compression stresses can only increase the fatigue limit in those cases in which the magnitudes of axial and tangential stresses differ appreciably, and that the greatest increases are obtained with metastable structures. S. K.

Simplified Determination of Fatigue Resistance of Steel and Other Metals. A. B. Lamberg. (Génie Civil, 1948, vol. 125, No. 15, pp. 434–435). An earlier article (Génie Civil, 1946, Feb. 1) has shown that the fatigue limit in tension-and-compression can be calculated from the limit of proportionality, the yield point and the ultimate tensile stress; this paper simplifies the calculations.—J. P. S.

The Elastic Modulus and the Fatigue Limit. A. Kammerer. (Comptes Rendus, 1948, vol. 227, Nov. 29, pp. 1144–1145). The author shows that the existence of two coefficients of viscosity (one practically nil for quasi-instantaneous elongation, the other finite for continuous flow as a function of time) and the variation of the elastic coefficients during deformation are sufficient to explain the static and dynamic (periodic) mechanical properties in tension and in flexion of such diverse materials as indiarubber, plastics, and metals.—A. E. C.

Some Notes on Fatigue Failures in Aircraft Parts. N. E. Woldman. (Iron Age, 1948, vol. 162, Dec. 9, pp. 98–101). A number of examples of fatigue failure in aero-engine and accessory parts are examined. Various causes are adduced, including the presence of stress raisers due to grinding cracks, to inclusions, and to defects of design.—J. P. S.

Portable Hardness Tester for Sheet Metal. Sh. S. Manevich. (Zavodskaya Laboratoriya, 1948, No. 3, pp. 378–379. [In Russian]: [Abstract] Engineers' Digest (London), 1948, vol. 9, Dec., p. 412).

The Determination of the Critical Speed of Hardening under Industrial Laboratory Conditions. I. F. Afonskii. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1267–1268). [In Russian]. The dilatometric determination of the critical cooling speeds for steel specimens is described and some examples are given.—S. K.

The "Warman" Penetrascope. (Machinery Lloyd, 1948, vol. 20, July 17, pp. 110–111 : [Abstract] PERA Bulletin, 1948, vol. 1, Oct., p. 715). The "Warman" Penetrascope is a diamond pyramid hardness tester which is fully self-contained and portable. It has a vice which enables it to be used for bar, sheet, etc., and it can also be utilized on large flat surfaces, for which purpose it is mounted on a rubber-wheeled platform. The load is applied hydraulically by turning a handwheel and the main electricity supply is stepped down by a transformer to supply the light used to illuminate the indentation seen through the microscope.

An End-Quenched Bar for Deep Hardening Steels. G. DeVries. (American Society for Metals, Oct., 1948, Preprint No. 22). A description is given of a test to give the relative hardenabilities of deep-hardening steels. A 1-in. dia. bar 6 in. long was end-quenched from the austenitizing temperature in a fixture so constructed that the top of the bar was kept at approximately 1200° F. (650° C.) during the quench. This made the temperature in the bar a function of the distance from the quenched end and allowed the steel to transform isothermally at the various temperatures. After the bar had been in the fixture for an hour, it was taken out and given an overall quench. The austenitic areas then transformed to martensite. The amount of transformation at each temperature was determined by making hardness

measurements along the side of the bar and comparing the hardness at each position with the maximum hardness. By comparing the loss in hardness at various points with the temperature at these points during the quench, the relative amount of transformation at any temperature could be estimated and thus the relative hardenability of different steels could be determined.

The Effect of Alloying Elements on the Hardness of Steel. L. F. Keeley. (Machinery Lloyd, 1948, May, pp. 53–56: [Abstract] Mécanique Documentation, 1948, vol. 3, Aug.–Sept., p. 1).

The Hardenability of Steel. (Tecnica Metallurgica, 1948, Mar., pp. 126–131: [Abstract] Mécanique Documentation, 1948, vol. 3, Aug.–Sept., p. 2). A review is given of the work of English and American investigators on the hardenability of steel.

"H" Band Steels Aid Heat Treaters. D. H. Ruhnke, E. T. Walton, and P. R. Wray. (Steel, 1948, vol. 123, Dec. 13, pp. 88–90, 115). The satisfactory results coming from the use of constructional alloy steels to "H" Band specifications are outlined. (*See* "Experience with 'H' Band Hardenability Specifications for Automotive Steels," Journ. I. and S.I. 1949, vol. 161, Feb., p. 162).—J. P. S.

The Application of Niobium to the Continued Toughness of Chromium–Molybdenum Steels at 1022° F. Ya. S. Gintsburg, K. A. Lanskaya and A. V. Ctanyukovich. (Kotloturbostroenie, 1948, Jan.–Feb., pp. 17–19 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 16). The effect of niobium on the resistance of various chromium–molybdenum steels containing from 2% to 7% chromium and 0·5% of molybdenum is discussed, and the toughness of these steels at 1022° F. is examined.

A Method for Measuring Wear. (Production Engineering and Management, 1948, vol. 22, Aug., p. 54: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 32). Investigations conducted at the National Bureau of Standards led to an adaptation of a diamond indentation method of measuring wear. A sensitive measuring instrument has been developed to measure extremely small increments of wear as little as one hundred-thousandth of an inch under favourable conditions.

A Theoretical Discussion of Pitting Failures in Gears. R. Beeching and W. Nicholls. (Proceedings of the Institution of Mechanical Engineers, 1948, vol. 158, No. 3, pp. 317–326). The paper is primarily concerned with the theoretical consideration of the stresses that cause surface failure in gear teeth. Methods of calculating the permissible line load between contacting cylindrical surfaces for static or cyclic conditions are considered, and the probable effects of friction are discussed qualitatively. Maximum permissible case thicknesses are suggested for case-hardened steel components of varying core strength when subjected to contact stresses of the type encountered in gears, rollers, and cams.—R. A. R.

Formation and Properties of Martensite on the Surface of Wire Rope. J. H. Corson. (Wire and Wire Products, 1948, vol. 23, Oct., pp. 869–875, 1001). The life of the surface strands of wire rope is discussed with special reference to the formation of martensite. There is evidence that during abrasion the surface layer is heated above the critical point and then cooled by the metal underneath at much faster than the critical cooling rate so that 100% martensite is formed. Tests are described in which specimens of 0·071 to 0·078 in. in dia. of steel wires (C 0·41%, 0·50%, 0·60%, and 0·78%) were struck a glancing blow in an Izod machine to produce a layer of martensite. They were then slowly bent over a mandrel and the angle at which the first cracks appeared in the martensite was noted. The ductility of the martensite decreased and its hardness increased with increasing carbon content. The practical implication is that the danger of wires breaking due to formation of martensite is considerably reduced if the carbon content is 0·55% or lower.—R. A. R.

Magnetic Materials. G. FitzGerald-Lee. (Electronic Engineering, 1948, vol. 20, Nov., pp. 351–353). Data are presented on the magnetic properties of permanent magnet alloys.—R. A. R.

Electric Conductivity of Ferromagnetic Substances at Low Temperatures. S. V. Vonsovsky. (Journal of Experimental and Theoretical Physics, U.S.S.R., 1948, vol. 18, Feb., pp. 219–223 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 12). The computation of electrical resistance of ferromagnetic substances at low temperatures is based on the conductivity of 'external' s-electrons and the conditions of magnetization of 'inner' d-electrons. Collisions of s-electrons and 'ferromagnetism' ('back surge' of d-electrons) during magnetization near saturation, at temperature T_3, causes accidental electrical resistance, specifically for ferromagnetic substances.

German Magnetic Alloy Has Important Applications. G. W. Elman and E. A. Gaugler. (Power Generation, 1948, vol. 52, Sept., pp. 64–67: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 10). The authors deal with the significance and importance of magnetic alloys having rectangular hysteresis loops in the design of contact rectifiers and magnetic amplifiers. They refer especially to alloys of the iron–nickel and iron–nickel–cobalt series developed in Germany during the war.

Design and Applications of a New Metals Comparator. D. E. Bovey. (Instrument Society of America: Instrument Practice, 1948, vol. 2, Oct., pp. 494–498). A description is given of the "Metals Comparator," developed by the General Electric Company, with which metal and non-metallic parts can be tested by magnetic methods and compared with standard materials. The oscillator can supply current to the test coil at frequencies of 50, 250, 500, 1000, 2500, 4000, and 10,000 cycles/sec.—R. A. R.

Thermo-Electricity. A Survey of Factors Affecting the Thermo-Electric Power of Metals. D. Hadfield. (Iron and Steel, 1948, vol. 21, Nov., pp. 478–482). A survey is presented of the work of various investigators on factors influencing the thermoelectric properties of metals, the most important of these factors being chemical composition, previous mechanical and thermal treatment, their state of strain (elastic or plastic), and (if ferromagnetic) their magnetization. The chief applications of these studies has been on the recovery of various metals from the effects of cold work, and the solution of solute atoms in a metal at different temperatures. Possible future applications are discussed and a bibliography is appended.—J. C. R.

Electric Charge of the Carbon Particles Dissolved in γ-Iron. T. A. Lebedev and V. M. Guterman. (Comptes Rendus (Doklady) de l'Académie des Sciences, U.R.S.S., 1948, vol. 60, pp. 1201–1203: Chemical Abstracts, 1948, vol. 42, Oct. 10, col. 7163).

Calculation of the Heat of Fusion of the Carbide and Silicide of Iron. E. I. Akhumov. (Journal of Applied Chemistry, U.S.S.R., 1948, vol. 21, Mar., pp. 227–234 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Mar., p. 14). Calculations are presented, based on literature for melting points of the system Al–Si, Fe–FeSi, and Fe–Fe_3C. These values agree with those obtained by the use of Le Chatelier's equation, if it is assumed that the silicide and carbide molecules each contain six atoms of iron in the liquid state: $(FeSi)_6$ and $(Fe_3C)_2$.

Ultrasonic Weld Inspection. (Steel, 1948, vol. 123, Dec. 13, p. 88). A new type of ultrasonic transmitter head is described, in which the beam of ultrasonic vibrations is emitted at an angle to the surface on which it is placed. This faciltates the location of flaws and inclusions in welded plates, both flat and curved, as, after repeated reflection from the faces of the plate, the impulses travel to the edge where they are reflected and return. Part of the beam is reflected by any discontinuity; this is indicated in the usual way on a cathode-ray tube. The same head can also be used for examining cylindrical objects such as bars and studs.—J. P. S.

Supersonic-Radiographic Inspection. (Production Engineering and Management, 1948, vol. 22, Sept., p. 56: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 28). A combination of the two types of inspection is recommended for best results. On completion of supersonic inspection of butt-welding in pressure containers, the most defective portions (about 10%) were given a radiographic check, since the supersonic method gives little quantitative information concerning the nature and extent of defects.

Damping Capacity. R. F. Hanstock. (Metal Industry, 1948, vol. 73, Nov. 12, pp. 383–385; Nov. 19, pp. 411–413). The usefulness of damping capacity measurements at both low and high stresses for the investigation of the properties and constitution of metals and alloys is discussed. Methods of measuring damping capacity are described, and it is shown

how the data can be applied to the estimation of the probability of fatigue failure.—R. A. R.

X-Ray Measuring Strains in Metal. (Steel, 1948, vol. 123, Nov. 29, pp. 79–80, 90). The application of X-ray diffraction to the measurement of elastic strain in metals is described, with special reference to its use in fatigue studies.—J. P. S.

X-Ray Line Broadening in Cold-Worked Metals. M. S. Paterson and E. Orowan. (Nature, 1948, vol. 162, Dec. 25, pp. 991–992). Observations on specimens deformed at low temperatures show that X-ray line-broadening is not due to recovery or recrystallization, and is limited by the circumstance that the shear stress cannot rise beyond the yield point of the material, which depends on the preceding plastic strain. Stresses of the order of the theoretical shear strength never occur, except in the centre zone of dislocations, and contribute only to the background in X-ray photographs. Confirmation of this is given by photoelastic stress measurements on transparent crystals, where it is found that most of the volume is not stressed beyond the macroscopic yield value; the high stresses are concentrated in the small volume occupied by the glide zones. Further connection between yield stress and line broadening is shown when the temperature is changed during deformation, as the curve of line breadth tends towards values characteristic of the new temperature not spontaneously with the course of time, but only if additional deformation is carried out.—J. P. S.

Further Investigation on the Graphitization of Piping for the EEI and AEIC. A. M. Hall and S. L. Hoyt. (Transactions of the American Society of Mechanical Engineers, 1948, vol. 70, Nov., pp. 847–853). Data are given of graphitization tests with plain-carbon low-aluminium steels, carbon–molybdenum steels, chromium–molybdenum steels, and molybdenum–vanadium steels.—J. C. R.

Some 1000° F. Steam-Pipe Materials. E. L. Robinson. (Transactions of the American Society of Mechanical Engineers, 1948, vol. 70, Nov., pp. 855–865). Long-time creep and rupture test results on molybdenum–vanadium steel pipe are presented and compared with results on low-chromium–molybdenum steel pipe. The former steel showed superior long-time strength at high temperatures.—J. C. R.

High Silicon Cast Iron for High Temperature Service. W. H. White and A. R. Elsea. (Iron Age, 1948, vol. 162, Nov. 4, pp. 106–108). High silicon (5–7%) cast iron has proved very resistant to growth at high temperatures. It is found that, though it is more brittle at low temperatures than ordinary cast iron, above 500° F. it becomes less brittle. J. P. S.

Tests below 300° F. Minus Prove Low Temperature Value of New Alloy Steel. (Inco Magazine, 1948, vol. 22, Summer Issue, pp. 16–19, 26: [Abstract] Metals Review, 1948, vol. 21, Sept., pp. 10, 12). Welded pressure vessels of 8·5% nickel steel withstood blows of 1500 ft.lb. on welds when filled with liquid nitrogen, while carbon steel shattered at under 1000 ft.lb.

Testing Turbine Wheels. (Aero Digest, 1948, vol. 57, Aug., p. 57: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 28). A method is described for proving high-test, heat-resistant steel alloys by subjecting discs of such materials to centrifugal force at 35,000 r.p.m. and temperatures up to 1750° F. High-speed photographs enable engineers to study test wheels as they break.

Creep-Resisting Alloys for Gas Turbines. A. J. Zuithoff. (Ingenieur, 1948, May, pp. MK 53–57 [in Dutch]: [Abstract] Mécanique Documentation, 1948, vol. 3, Oct., p. 1). An account is given of recent developments in Germany, the United States, and Britain, in heat-resisting alloys for gas turbines and turbocompressors. Compositions and creep-resisting properties are given.

Investigation on Dissolved Gases in Cast Iron. J. E. Hurst. (Pig Iron Rough Notes, 1948, Spring–Summer Issue, pp. 4–7: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 12). This is the first part which deals with results of observations on gases evolved on solidification of molten pig iron and the influence of casting temperature on the carbon dioxide, carbon monoxide, hydrogen, and nitrogen content.

Cathodes with Low Potentials for Decreasing the Evolution of Hydrogen. N. P. Fedot'ev, N. V. Berezina, and E. G. Kruglova. (Journal of Applied Chemistry, U.S.S.R., 1948, vol. 21, Apr., pp. 317–328 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 4). Evolution of hydrogen causes difficulty during various electrochemical processes. Fifteen types of low-carbon and alloy steels were evaluated in an attempt to decrease this phenomenon but the results were not encouraging. However, it was found that special surface treatments such as sand-blasting, or electroplating with certain nickel alloys, gave good results.

Researches on the Mechanism of the Pickling Embrittlement of Steel.—III. Influence of a Prior Anneal in Hydrogen of Armco Iron on the Subsequent Diffusion of this Gas in the Cold in the Metal. P. Bastien. (Revue de Métallurgie, Mémoires, 1948, vol. 45, Sept., pp. 301–311). The tests described were made on six different casts of Armco iron. The hot-rolled material, 7 mm. in dia., was wire-drawn to 2 mm. dia. without intermediate annealing, and then normalized at 950° C. for 10 min. and air-cooled. The wires were then annealed for 48 hr. at 880° C. in argon or in hydrogen. The resulting polycrystalline metal was then charged with hydrogen either by immersion for 48 hr. in a 10% solution of hydrochloric acid in water or by cathodic electrolysis in this solution (2·5 V., 5·25 m.amp./sq. cm.). The brittleness as annealed in the controlled atmosphere, or immediately after hydrogen treatment, or finally, after remaining in mercury for 1000 hr. at 15° C., followed in some cases by 500 hr. at 60° C, was determined by the folding test previously described by the author. The results are recorded and discussed in detail. The work again underlines the importance of the part played by the enrichment in hydrogen of the layer of adsorbed gas on the diffusion of hydrogen into iron and its later departure, with concomitant development of brittleness. It also shows what precautions are needed in interpreting diffusion tests in single crystals. The fact that the single crystal is not rendered brittle by acid pickling is not due to the absence of intercrystalline joints but to the modification of the chemical activity of the metal itself, particularly of its surface, under the influence of the hydrogen anneal carried out during the preparation of single crystals of iron, for this effect is found in polycrystalline specimens that have had the same treatment. After a hydrogen anneal very low carbon steels of similar compositions can behave very differently; in some of them intergranular fissures will appear, with the development of permanent brittleness in the cold as a consequence. As such fissures may be produced during the preparation of single crystals there is a danger that they also may introduce errors in the interpretation of results. This work confirms that hydrogen causing brittleness will diffuse easily; a sufficiently long heating at 60° is enough to make it disappear in most cases. It is certain that after this heating hydrogen is still present in the structure, but it has no perceptible mechanical influence. [This is a continuation of a series of papers, *see* Journ. I. and S.I., 1947, vol. 156, July, p. 444]. A. E. C.

Effects of Boron Additions on Malleablization of White Cast Iron. J. E. Micksch, H. A. Fabert, jun., and G. M. Cover. (American Foundryman, 1948, vol. 14, Aug., pp. 30–37). The object of this investigation was to obtain data on the microstructure of white cast iron having very small boron additions. The specimens chosen had boron contents varying from nil to 0·05%, and one specimen had 1% boron. They were charged into the annealing furnace at 2-hr. intervals for a period of 4 days, the temperature being maintained at 1700° F. The method and rate of cooling are outlined, and numerous photomicrographs are given showing the structure of the irons after this heat-treatment. The following conclusions were drawn: (1) At approximately 0·0025% boron a complex carbide began to appear, the amount increasing with increasing boron; (2) graphite nucleation was noticeable at 0·0025% boron and increased with increasing boron; (3) boron above 0·0025% refined the ferrite grain and graphite particle size; (4) pearlite decreased with increasing boron content, the most noticeable change occurring between 0·0012% and 0·0025%; (5) an optimum boron content for the maximum acceleration of annealing appeared to be within the range 0·0012% to 0·0025%; and (6) irrespective of boron content the coarseness of pearlite lamellæ increased with the shorter times at the upper holding temperature of 1700° F.

Phosphorus in Cast Iron. E. Piwowarsky. (Pig Iron Rough Notes, 1948, Spring–Summer Issue, pp. 18–23: [Abstract] Metals Review, 1948, vol. 21, Oct., p. 8). Data are given on the effect of phosphorus on structure and mechanical properties.

Reinforced Cast Iron. E. Piwowarski. (Iron Age, 1948, vol. 162, Dec. 9, pp. 93–96; Dec. 13, pp. 99–101). Following up earlier Russian work, experiments have been carried out on the reinforcement of cast iron with cast-in steel inserts, placed to withstand tensile stresses in the same way that the reinforcement in a concrete beam withstands them. It is concluded that the increase in strength exceeds that attributable to the relative area of the steel reinforcement, in that a 30% increase in strength results from a 5–10% reinforcement. To obtain the best results, pouring temperatures of 1350° C. to 1420° C. are required. The steel used should contain 1·5–3% of silicon so that the formation of a brittle cementite network in the fusion zone may be avoided; the use of a steel with this silicon content, and a carbon content of 0·45–0·65% will ensure, in addition, that coarse grain growth does not occur if the reinforcement bars are of cold-worked material. The author believes that there are considerable possibilities in this method of construction.—J. P. S.

Gray Cast Iron—Relationship of Composition and Properties. R. G. McElwee. (American Foundryman, 1948, vol. 14, Aug., pp. 46–49). **Relationship of Section Size, Hardness and Composition of Gray Cast Iron.** R. G. McElwee. (SAE Journal, 1948, vol. 56, Nov., pp. 33–35). The author considers the function of the various elements in grey cast iron, and examines the advantages of a higher carbon content, which include lower shrinkage, higher deflection and, with a proper adjustment of silicon, any reasonable strength and hardness. The necessity for feeding with external risers is reduced and castings are sounder. The fallacy of attempting to regulate the wear performance of an iron on the basis of Brinell hardness is discussed.—J. C. R.

Fourth Report of the Research Committee on High-Duty Cast Irons for General Engineering Purposes: Acicular Cast Irons. J. G. Pearce. (Proceedings of the Institution of Mechanical Engineers, 1948, vol. 158, No. 3, pp. 327–333). The manufacture, properties, and applications of acicular cast irons are reported. These irons can be produced in any type of melting unit, but where the amount required is sufficient the cupola is recommended. The molten metal is inoculated in the ladle with a graphitizer, and if 75% ferrosilicon is used, this should yield an additional 0·3–0·6% of silicon in the molten metal; the silicon in the charge materials should be reduced by a like amount. The permissible additions of molybdenum, nickel, copper, and chromium are given. The amount of vanadium normally present in the charge materials does not cause difficulty in the production of acicular iron, but no specific additions of vanadium should be made. The mechanical properties of acicular iron, particularly the shock resistance, are well in excess of the best high-duty irons hitherto known.—R. A. R.

Alloy Iron Castings Show Tensile Strength Almost 60,000 psi as Cast. (Inco Magazine, 1948, vol. 22, Summer Issue, pp. 4–6: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 10). Properties and applications are given of "Ni-Tensylirons" (new grey-iron alloys containing variable amounts of nickel and molybdenum, up to 3% and 0·6% respectively.

Recent Applications of Alloy Cast Irons. A. B. Everest. (Métallurgie, 1948, vol. 80, Nov., pp. 41–43). The properties and applications of some modern high-strength alloy cast irons are reviewed.—J. C. R.

Niresist Special Cast Iron and Its Many Applications. (Technische Rundschau, 1948, Mar., pp. 4–6: [Abstract] Mécanique Documentation, 1948, vol. 3, Aug.–Sept., p. 1). Notes are given on the composition, physical, mechanical, and electrical properties of Niresist and its applications.

Mechanical Properties and Composition of Castings for the Base Supports of a Hydro-Turbine. V. I. Smirnov. (Kotloturbostroenie, 1948, Mar.–Apr., pp. 22–24 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 12). Results are presented of investigations on the mechanical properties and composition of iron castings tempered from 350° and 550° C. The castings were samples from two base supports which had been long in service.

Problems of Materials and Design for Steam and Gas Turbines. H. Niermeyer. (Archiv für Metallkunde, 1948, vol. 2, No. 5, pp. 145–154). The materials for, and the design of, the different parts of steam and gas turbines are discussed with special reference to the discs and blades. Recommendations for blades, both of all-metal and of metal-cored ceramic construction, are made.—R. A. R.

The Influence of Temperature and Time of Heating on the Reduction of Residual Stress in Austenitic Steels. L. A. Glickman and V. P. Tyekht. (Kotloturbostroenie, 1948, Mar.–Apr., pp. 12–16 [in Russian]: [Abstract] Metals Review, 1948, vol. 21, Sept., p. 42). The residual stress in discs of austenitic chromium–nickel steel (type YeYa 2T) has been artificially induced using a heat-treatment. The influence of the temperature of drawing in the temperature range of 600° to 850° C. on the decrease of residual stresses has been studied. The method of investigation and computation of data using a formula of Sachs is explained.

Properties of Type "CA" Cast Alloys. E. A. Schoefer. (Alloy Casting Bulletin, 1948, Oct., pp. 1–7). The results are presented of investigations of the effects of composition and heat-treatment on the properties of cast chromium steels (Cr 11·5% to 14·0%, Ni up to 4%). The rate of corrosion in nitric acid tends to a maximum after tempering at 1100° F. Increasing the nickel content causes a marked increase in hardness and drop in ductility after tempering at 1500° F. Silicon lowers the impact strength of the alloys tempered at 600° F. but does not materially affect the other properties. Molybdenum causes a general reduction in the mechanical properties of the alloys tempered at 600° F. Increasing the columbium from 0 to 1·28% decreases the ultimate tensile strength from about 200,000 to 40,000 lb./sq. in. in the oil-quenched condition; this is due to the strong carbide-forming tendency which also improves the corrosion resistance after tempering in the 900–1200° F. range.—R. A. R.

The Microstructure and Mechanical Properties of Cast Steels. M. F. Hawkes and B. F. Brown. (American Society for Metals, Oct., 1948, Preprint No. 17). The microstructures of a large number of plain carbon, low-alloy, and medium-alloy cast steels were examined after various annealing and normalizing treatments. The temperature at which austenite transforms on cooling is the fundamental variable controlling microstructure. It was found that as this temperature is lowered by virtue of increased cooling rate or hardenability, the structures were successively: (1) Dendritic blocky ferrite plus pearlite, (2) random blocky ferrite plus pearlite, (3) Widmanstätten ferrite plus pearlite, and (4) martensite. The maximum ductility obtainable in a cast steel is gained by quenching the steel to martensite and then tempering it at a high temperature. Little or no loss in ductility and appreciable gain in strength are obtained by moderately rapid cooling (*e.g.*, in air) which forms Widmanstätten ferrite, in place of slow cooling which forms blocky ferrite. In determining the effect of microstructure on the mechanical properties, the authors used the standard etching reagents supplemented by a special etchant consisting of an ether solution of picric acid and Zephiran chloride (an organic chloride).—R. E.

Effect of Vanadium on the Properties of Cast Carbon and Carbon–Molybdenum Steels. N. A. Ziegler, W. L. Meinhart, and J. R. Goldsmith. (American Society for Metals, Oct., 1948, Preprint No. 18). An investigation was made of (*a*) carbon–vanadium, (*b*) 0·5% molybdenum–vanadium and (*c*) 1% molybdenum–vanadium cast steels, in which vanadium ranged from 0 to 0·3% and carbon from 0·05% to 0·3% in each group. Results showed that thermal sluggishness was increased by the combined effects of carbon, molybdenum, and vanadium, but not by vanadium alone, in the carbon–vanadium steel group. Some residual delta ferrite (untransformed) was found in the structure of the low carbon, high molybdenum, and high vanadium compositions. Increasing vanadium contents reduced the pearlite grain-size and produced some extremely fine spheroidal carbides. Vanadium moderately increased tensile strength, yield point, proportional limit and hardness, slightly reduced ductility, and considerably reduced impact resistance. Vanadium-bearing steels in the as-cast condition appeared more brittle than similar compositions without vanadium, but, when properly heat-treated, the brittleness was eliminated, although impact resistance remained lower.—J. C. R.

A Study of the Properties of 0·5 per cent. Chromium–0·5 per cent. Molybdenum Steel Pipe. R. C. Fitzgerald, A. B. Wilder, G. V. Smith, and A. E. White. (Transactions of the American Society of Mechanical Engineers, 1948, vol. 70, Nov., pp. 867–877: Welding Journal, 1948, vol. 27, Sept., pp, 457-s.–469-s.) A study of the mechanical properties including creep, and of the welding and fabrication characteristics of steel containing 0·5% of chromium and 0·5% of

molybdenum, designed for high-temperature service, has shown this grade to be essentially similar to 0·5% molybdenum steel without chromium. High-temperature exposure tests have shown the steel, whether deoxidized with aluminium or not, to be resistant to graphitization in butt-welded pipe as well as bead-weld tests lasting up to 15,000 hr. at 1025° F., and 12,000 hr. at 1100° F. Scaling, hardness, and notch-impact tests, before and after air exposure at elevated temperature have indicated that only slight oxidation and little or no embrittlement may be anticipated in service.

The Structural Stability of Several Cast Low-Alloy Steels at Elevated Temperatures. V. T. Malcolm and S. Low. (Transactions of The American Society of Mechanical Engineers, 1948, vol. 70, Nov., pp. 879–884). The authors have investigated in relation to structural stability: (1) The effect of aluminium on a cast carbon–molybdenum steel; (2) the effect of furnace practice on a cast carbon–molybdenum–vanadium steel; (3) the effect of chromium on a cast carbon–molybdenum steel; (4) the effect of vanadium on a cast carbon–molybdenum steel; (5) the effect of various combinations of chromium, vanadium, and titanium on a cast carbon–molybdenum steel; and (6) the effect of chromium, nickel, and high molybdenum on a cast carbon–molybdenum steel. Physical properties of the alloys are given in detail and data are presented of results of McQuaid-Ehn, tensile, Jominy hardenability, creep, and weldability tests.—J. C. R.

Effect of Niobium on the Properties of Low-Tungsten High-Speed Steels. N. T. Gudtsov and L. D. Mashtakova. (Bulletin de l'Académie des Sciences, U.R.S.S., Classe des Sciences Techniques, 1947, pp. 1629–1637: Chemical Abstracts, 1948, vol. 42, Oct. 10, col. 7219). Steels containing C 0·86–1·02%, Si 0·71–0·84%, W 1·7–3·1%, Cr 8·08–8·90%, Ni trace–0·20%, V 2·48–2·94%, Nb 0·0–2·95%, P 0·039–0·044% and S 0·028–0·038% were heat-treated and examined for microstructure, hardness, and cutting properties. Addition of niobium to these steels decreased forgeability, ductility, and the cutting life of a tool. Maximum hardness of niobium-bearing steels (64·0–64·5 Rockwell C) was obtained by quenching from 1220° and drawing three times at 540°.

Mechanical Properties and Practical Behaviour of Some High-Speed Steels. M. Ongaro. (Metallurgia Italiana, 1948, vol. 40, Jan–Feb., pp. 19–28: [Abridged translation] Revue de l'Industrie Minérale, 1948, Nov., pp. 753–755). The author compares the mechanical properties and behaviour of three Italian war-time (1939–45) high-speed steels, with two pre-war steels, one of which contained 10% of cobalt. The author suggests an optimum composition for high-speed steel with C 0·95–1·05%; Cr 4·3–4·7%, W 9–10%, and V 1·8–2·2%.—R. F. F.

Mild Steel in Ship Construction. W. Barr and A. J. K. Honeyman. (Institution of Engineers and Shipbuilders in Scotland, Nov., 1948, Preprint). After reviewing the early applications of steel plate for shipbuilding, its present-day characteristics are discussed. The Izod and Charpy impact tests are described and the following aspects are dealt with: (*a*) Effects of steelmaking, rolling, and heat-treatment on the results of impact tests; (*b*) ageing; (*c*) effect of variations in the impact-testing conditions; and (*d*) the effect of welding. American work on notch sensitivity continues to use the temperature-transition range of tough to brittle fracture as the criterion of performance, but the authors do not consider this a suitable one to apply to ordinary mild steel.

Selecting Materials to Reduce Maintenance. W. H. Sparr. (Iron and Steel Engineer, 1948, vol. 25, Sept., pp. 134–138). The author considers means of reducing maintenance costs by improving the design of parts to prevent or reduce failures caused by stress, and by using materials having better mechanical properties, which will resist wear and corrosion.—J. C. R.

Influence of Low Temperatures on the Mechanical Properties of 18/8 Chromium–Nickel Steel. D. J. McAdam, jun., G. W. Geil, and Frances J. Cromwell. (American Society for Metals, Oct. 1948, Preprint No. 20: Steel Processing: 1948, vol. 34, Nov., pp. 592–594). *See* Journ. I. and S.I., 1948, vol. 160, Nov., p. 336.

Mechanical Properties, Including Fatigue, of Aircraft Alloys at Very Low Temperatures. J. L. Zambrow and M. G. Fontana. (American Society for Metals, Oct., 1948, Preprint No. 19). Aluminium and aluminium alloys, a magnesium alloy, low-alloy steels, 18/8 stainless steel, Stainless "W," an 8·5% nickel steel, and aluminium-bronze were subjected to mechanical tests in the range room temperature to −253° C. (− 423° F.). Data are reported on fatigue tests at 25°, −78°, and −196° C., impact tests at 25°, −78°, −127°, −192°, and −253° C., hardness tests at 25°, −78°, and −192° C., and tensile tests at 25°, −78°, and −196° C. Equipment, techniques, and precautions used in performing these tests are described. The alloys, without exception, showed an increase in fatigue strength with falling temperature. Fatigue strength appeared to be related to tensile strength. Charpy impact tests showed no general correlation between temperature and impact values. Ferritic steels showed a sharp decrease in impact values with falling temperature; austenitic steels showed a gradual decrease. The hardness of all materials increased with falling temperature, but it is shown that hardness depended on previous heat-treatment as well as the test temperature. Tensile strength and yield strength increased with falling temperature. Reduction of area decreased generally with falling temperature, but 18/8 stainless steel and 8·5% nickel steel showed a slight increase at −78° C. over that obtained at room temperature.—J. C. R.

British High Strength Structural Steels. (Civil Engineering (London), 1948, Aug., pp. 400–404). A review is presented of the properties and applications of British high-strength structural steels.

Graphitic Nitralloy. V. O. Homerberg. (Iron Age, 1948, vol. 162, Nov. 18, pp. 99–101). Graphitic nitralloy contains carbon 1·2–1·3%, manganese 0·5% approx., aluminium 1·35–1·50%, chromium 0·2–0·4%, and molybdenum 0·25% approx. Oil-quenching from 1650° F., and tempering at 1375°–1400° F. reduces the combined carbon to 0·3–0·5%, the rest being deposited as temper carbon. Nitriding properties are very satisfactory; it is claimed that the graphite, where it occurs in the case, acts as a lubricant, and if particles are dislodged the holes act as oil wells.—J. P. S.

Designation of Types of Steels in U.S.S.R. St. Bukowski. (Inzyn i Budow, 1948, May, p. 233 [in Polish]: [Abstract] Mécanique Documentation, 1948, vol. 3, Nov., p. 1). A table gives different types of steels produced in the U.S.S.R. with their mechanical properties.

Raw Materials, Testing and Working-Up of Deep-Drawing Sheets. (Osterreichischer Maschinenmarkt und Elektrowirtschaft, 1948, vol. 3, Oct., pp. 317–319). The requirements of the German standard specifications for steel sheets for deep-drawing are discussed.—R. A. R.

METALLOGRAPHY

A Vacuum Furnace for High-Temperature Microscopy. D. G. Nickols. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 415–416). A vacuum furnace has been constructed to enable metal specimens to be kept under microscopical examination while at temperatures up to 950° C. It incorporates a mica observation window and gaskets of heat-resistant silicone rubber. Constructional details are given and future developments indicated.

A Method of Identifying Manganese-Sulphide Inclusions in Steel. J. H. Whiteley. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 365–366). A method is described of identifying manganese-sulphide inclusions by means of Selvyt cloth soaked in a solution of silver nitrate and well washed.

The Structure of Carbides in Alloy Steels. Part I—General Survey. H. J. Goldschmidt. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 345–362). The present paper is the first of a series giving an account of X-ray work on carbides liable to occur in alloy steels, especially high-speed steels. It is mainly concerned with the structures of carbides formed by iron, chromium, tungsten, and molybdenum, but these are considered as part of a broader systematic survey of carbide-forming tendencies of alloying elements and their relation to crystal structure.

A brief account is given of the relevant metal–carbon systems. The carbide structures are described and discussed, and an attempt is made to correlate them with their stability in the presence of given elements.

There is a bibliography with ninety-three references.

A New Carbide in Chromium Steels. H. J. Goldschmidt. (Nature, 1948, vol. 162, Nov. 27, pp. 455–456). A new carbide phase has been discovered during the course of X-ray investigations on the carbides in chromium and tungsten steels; although of crystal structure identical with austenite,

it proved to be a true carbide of iron and chromium, having a face-centred cubic structure with interstitial carbon. The chromium/iron ratio and the carbon content vary however, so that the lattice appears to be a defective one. The author shows that this carbide, which he calls "ψ-phase," fits naturally into place when the known cubic carbides are arranged according to the periodic table. He suggests the following implication from this discovery : (1) Carbon must be used in interpreting structures of ferrite or martensite containing apparent austenite, as, for instance, in high-speed steels, 'persistent' austenite may involve ψ-phase or a solid solution of its type ; (2) its production in high-speed and magnet steels would induce physical properties intermediate between a hard carbide and the ductile austenite ; (3) as it is only stable at high temperatures, and tends to transform to either trigonal $(Cr,Fe)_7C_3$, $(Cr,Fe)_{23}C_6$, or cementite, or assemblies thereof, there is promise of precipitation hardening ; (4) as its lattice dimensions are favourable to the formation of solid solutions with austenite, the tendency to segregate from the matrix, and at the same time decompose, is likely to influence creep resistance and strength at high temperature; and (5) a synthetically prepared ψ-phase, being isomorphous with titanium carbide and cobalt, and probably intersoluble with tungsten carbide, may be of use in sintered hard-metal materials.—J. P. S.

Stabilization of Undercooled Austenite. P. P. Petrosyan. (Comptes Rendus (Doklady) de l'Académie des Sciences, U.R.S.S., 1948, vol. 59, pp. 1109–1111 : Chemical Abstracts, 1948, vol. 42, Oct. 10, col. 7217). If the cooling of steel in the martensite range is interrupted, further conversion of austenite into martensite on resumption of the cooling suffers a delay, *i.e.*, it begins only after a definite temperature lag of $\theta°$. Magnetometric recordings showed the magnitude of θ to increase with decreasing temperature t of the isothermal arrest, to pass through a maximum, then to decrease somewhat, and finally to rise sharply with further decreasing t. Furthermore, martensite is formed in the process of isothermal arrest in a certain temperature range below the martensite point ; its amount increases with decreasing temperature, passes through a maximum, and then falls to nearby zero at a certain critical temperature t_c at which no more martensite is formed in an arrest of the same direction. On eight different steel sorts, the maximum of θ and the maximum of the growth ΔM of the martensite phase in the isothermal arrest were found to lie at the same t ; similarly, θ is minimum at about $t = t_c$ where $\Delta M \sim 0$. An increase of the amount of isothermally formed martensite lengthens θ.

CORROSION

Corrosion Studies. A. L. Kimmel. (Florida Engineering and Industrial Experiment Station, College of Engineering, 1947, Bulletin No. 17 : [Abstract] Metals Review, 1948, vol. 21, Sept., p. 18). Mechanical, chemical, and electrical methods for the mitigation of corrosion are discussed and engineering data are given relative to the installation of cathodic protection systems in water tanks.

Causes of Steel Corrosion. I. Richards. (Organic Finishing, 1948, vol. 9, Aug. pp. 41–46 : [Abstract] Metals Review, 1948, vol. 21, Oct., p. 16). The theory of corrosion and the factors which cause it are discussed.

A Theory of Rust Formation on Iron. Y. Kauko. (Transactions of Chalmers University of Technology, Gothenburg, 1947, No. 61 : Chemical Abstracts, 1948, vol. 42, Oct. 10, col. 7224). A general theory of the corrosion of iron in the systems base–CO_2–H_2O and Fe–O_2 was developed on the basis of electrode potentials in the presence of various ions. The potential of iron in oxygen-saturated water gradually falls to a constant value, dependent on the oxygen pressure over the solution. The passive state of iron is not dependent on this pressure, however, and is due to the formation of more or less stable compounds. Gaseous oxygen alone cannot lead to heavy corrosion at ordinary temperatures. The rôle of hydrogen overvoltage in corrosion is discussed, and the effect of mechanical treatment and presence of oxygen on corrosion cells. A graph is presented of Fe (dissolved) against pH ; at fixed carbon dioxide pressures, straight lines result. These lines are intersected by a line $E = O$; at lower pH values than this line, corrosion takes place ; at higher values no corrosion takes place. Oxygen displaces this line towards higher pH values. The exact conditions for zero corrosion are difficult to calculate because of inaccurate values of the solubility product for $FeCO_3$, $Fe(OH)_2$, and $Fe(OH)_3$, the latter being the least important. New determinations of the solubility product are under way with corrections for hydrolysis and complex formation of the ions.

Fluorine Corrosion : (A) High Temperature Attack on Metals by Fluorine and Hydrogen Fluoride ; and (B) Behavior of Insulated Steel Parts in Fluorine Cells. W. R. Myers and B. DeLong. (U.S. Atomic Energy Commission, 1947, Report MDDC–1465 : [Abstract] Metals Review, 1948, vol. 21, Sept., p. 18). This report deals with the corrosion of a number of metals and alloys by fluorine at elevated temperaures. The data were obtained by exposing samples to fluorine in an electrically heated furnace equipped with a Monel tube. Results of a study of the attack on a number of metals and alloys by HF and HF-steam in equimolecular quantities are given, and results are reported of an investigation on the behaviour of steel parts anodically charged in an electrolyte of $KHF_2.HF$ at 90° C.

Resistance to Sensitization of Austenitic Chromium–Nickel Steels of 0·03% max. Carbon Content. W. O. Binder, C. M. Brown, and R. Franks. (American Society for Metals, Oct. 1948, Preprint No. 25). A study was made of low-carbon austenitic chromium–nickel steels to determine the effects of chromium, nickel, carbon, and nitrogen on their susceptibility to intergranular corrosion. The compositions investigated were Cr 16–25%, Ni 6·5–25%, C 0·005–0·05%, and N_2 0·002–0·15%. Additions of up to 3% molybdenum and small amounts of niobium were also investigated. Results showed : (1) Complete immunity from intergranular corrosion may be obtained if the carbon is held below 0·015% to 0·020% depending on the balance of the composition ; (2) if the carbon content is about 0·03%, complete immunity may be obtained by a small addition of niobium ; (3) partial immunity may be obtained in steels of balanced composition with a carbon content of 0·03% ; and (4) in 18% chromium–nickel steels containing 2% molybdenum, partial immunity may be obtained with a carbon content of 0·03%.—J. C. R.

Examination of Almelec and Steel/Aluminium Conductor Cables after 15 to 25 Years' Service. Part II. Observations Made on Steel/Aluminium Cables. J. Herenguel. (Revue de l'Aluminium, 1948, Mar., pp. 73–78). Most of the conductor cables examined contained a core of galvanized steel wire with two outside layers of aluminium wire, but some had only one outside layer of aluminium wire of greater diameter. The number of layers of aluminium wire and their size did not affect the galvanized coating of the steel core. The cables were generally in very good condition after 15 to 25 years' service, and a life of 50 years seemed possible.—J. C. R.

Cathodic Protection of Underground Structures. (Gas Age, 1948, vol. 102, July 8, pp. 25, 57–58 : [Abstract] Metals Review, 1948, vol. 21, Sept., p. 18). Tests were made to determine the value of attaching zinc cylinders to steel specimens as a means of preventing underground electrolysis or corrosion.

The Use of Chemicals for Retarding Corrosion. H. L. Bedell and V. W. Hatchett. (American Petroleum Institute, Thirteenth Mid-Year Meeting, May 10–13, 1948, pp. 9–18). The use of alkaline chemical agents in refinery equipment to retard the corrosion set up by acid materials in crude oil is described. The agents used are lime, caustic, and ammonia, or combinations of these. Pipeline systems for distributing the agents to the required points are described.

R. A. R.

A Résumé of Sohio's Experience in Overhead Condensing Equipment. E. N. Salathe. (American Petroleum Institute, Thirteenth Mid-Year Meeting, May 10–13, 1948, pp. 22–25). Some corrosion problems at No. 1 Refinery, Cleveland, Ohio, of the Standard Oil Company are discussed. To reduce the corrosion of exchanger tubes pH control of the aqueous condensate from the reflux accumulator was installed, and the pH was held between 6·8 and 7·2 by injecting ammonia into the system.—R. A. R.

Prevention of Corrosion in Refinery Heat-Exchanger Equipment. M. A. Furth. (American Petroleum Institute, Thirteenth Mid-Year Meeting, May 10–13, 1948, pp. 26–34). Corrosion problems experienced by the Pure Oil Company, Nederland, Texas, are outlined, with special reference to heat-exchanger tubes. For condensing and cooling service, with water as the coolant, inhibited Admiralty bronze has

been adequate except where ammonia and hydrogen sulphide are present under conditions which promote stress-corrosion or corrosion-fatigue failures. Copper–nickel (70/30) tubes are now being tried. Costs of welding, brazing, and silver-soldering steel tube plates are presented and discussed.—R. A. R.

Selection of Valve Materials for Petroleum Applications. H. O. Teeple. (American Petroleum Institute, Thirteenth Mid-Year Meeting, May 10–13, 1948, pp. 35–43). The metals, alloys, and other materials available for valves at petroleum refineries are listed and recommendations are made on the selection of materials to resist the attack of the acids, alkalis, water, brine, steam, and sulphur.—R. A. R.

Recent Developments in Cathodic Protection of Pipe Lines. N. P. Peifer and F. E. Costanzo. (Gas Age, 1948, vol. 102, Aug. 5, pp. 21–23 : [Abstract] Metals Review, 1948, vol. 21, Sept., p. 20). Two refinements in cathodic corrosion protection of bare underground steel pipelines are given. One depends on a refinement of the common method of determining the need for protection and on calculations of current densities required for protection. The other is the use of an expendable ribbon-type magnesium anode parallel to the pipe at varying distances computed from predetermined galvanic currents.

Fifteen Years Experience in Application of External Corrosion Mitigation Methods to a High Pressure Natural Gas Transmission Line. N. K. Senatoroff. (Corrosion, 1948, vol. 4, Oct., pp. 479–491). An account is given of the measures taken to protect the welded steel pipeline (12¾ in. outside dia.), 80 miles long, which supplies San Diego with natural gas, from external corrosion. The pipeline is buried and the soil conditions vary greatly. Coal-tar-base and asphalt-base protective coatings with appropriate wrappings were applied in some places, and petroleum grease in others, and cathodic protection is also used. Details of the costs and maintenance of the cathodic protection are given.

High Temperature Corrosion and Its Prevention. (Engineering and Boiler House Review, 1948, vol. 63, Oct., pp. 297–299). The corrosion of gas-swept heating surfaces of boilers is considered. The theories of L. B. Pfeil, W. H. J. Vernon, and H. H. Uhlig on scale formation are briefly explained, and the results of tests by W. H. Hatfield and W. F. Harlow are cited.—R. A. R.

ANALYSIS

Rapid Quantitative Analysis by X-Ray Fluorescence Method. M. A. Cordovi. (Steel, 1948, vol. 123, Dec. 20, pp. 88–94). Quantitative chemical analysis to a high degree of accuracy can be performed by X-ray fluorescent methods. The specimen is irradiated by X-rays and the secondary emission collimated and analysed by means of a rock-salt crystal and a goniometer employing a Geiger counter.—J. P. S.

Spectrographic Analysis in Metallurgy. J. Orsag. (Revue de l'Aluminium, 1948, May, pp. 151–159). An outline is given of the principles underlying qualitative and quantitative spectrochemical analysis, the equipment used, and the directions in which they can be applied.—J. C. R.

The Principles and Present Position of the Development of Polarographic Equipment and Procedures in the Works Laboratory. H. Moritz. (Metallwirtschaft, 1948, June, pp. 189–195). The principles of polarographic analysis are explained and the equipment is described. Details are then given of procedures for making determinations of zinc, copper, aluminium, and iron. The advantages and limitations of the process are discussed.—R. A. R.

Polarographic Determination of Iron. L. Meites. (Analytical Chemistry, 1948, vol. 20, Oct., pp. 895–897). In polarographic determination of iron by reduction from the ferric to the ferrous state, other ions such as copper, chromate, and vanadate interfere giving incorrect values of the polarogram. In the method described, an oxalato-ferrous complex is employed ; copper must be removed beforehand, but other ions do not interfere. Examples are given of the high accuracy of this method in determining iron in ferrovanadium and a number of non-ferrous alloys.—J. P. S.

A New Type of Recording Microphotometer with Direct Reading of the Intensity. M. Laffineur. (Comptes Rendus, 1948, vol. 227, Nov. 3, pp. 900–902). With this apparatus the local opacity or density of a spectrum photographed on film can be measured by comparison with a standard spectrum taken with the same spectrograph. Two beams of light, one focused on the ' test ' spectrum and the other on the standard spectrum, which is suitably graded, pass on to fall on a photoelectric cell. Two rotating perforated discs interrupt the beams so that the cell is acted on alternately by one or the other beam. If the intensities of the beams are not equal the cell operates an electric circuit by which a mirror is rotated to deflect the ' standard ' beam until it passes through a spot on the graded spectrum of density equal to that of the ' test ' spectrum. The movement of the mirror is recorded optically, and as the ' test ' spectrum is traversed so a density curve is traced.—A. E. C.

A Rapid Method of Spectrographic Analysis. H. R. Clayton. (Journal of the Society of Chemical Industry, 1948, vol. 67, July, pp. 270–273). A process has been developed to enable spectrographic analyses to be carried out in approximately 10 min. This speed has been attained chiefly through attention to the methods of processing the photographic plates, which are developed and fixed in ultra-rapid reagents, washed for a minimum time, and dried in an oven designed for the purpose. A single analysis can be carried out in 8½ min. with an error of ± 4% using fast photographic plates or in 9½ min. with an error of ± 3% using a slower plate. An addition of about 2 min. to either of these times permits duplicate determinations to be made with a reduction of some 30% in the analytical error.

Magnetic Stabilizer for Direct-Current Arcs in Spectroscopy. G. C. B. Cave. (Analytical Chemistry, 1948, vol. 20, Sept., pp. 817–821). An instrument is described which eliminates wandering of the central portion of a direct-current arc used in spectrographic analysis. Two photoelectric cells are placed at the two vertical edges of an enlarged image of the arc produced by an aluminized mirror, with a central hole placed between the arc and the slit of the spectrograph, and a glass lens. If the arc wanders to one side or the other the photoelectric cells are illuminated unequally, and, by means of a direct-coupled amplifier they energize an electromagnet which immediately recentres the arc by reaction between its field and the field due to the arc current. Examples given of spectrographic analysis of a limestone, a complex sulphide ore, and fluorspar show that in many cases an improvement in precision is gained ; this is least in the case of the most volatile metals studied, where it appears that the shape of the electrode is significant. Indications are given that it is feasible to apply magnetic stabilization to an alternating-current arc as well.—J. P. S.

The Production of Constant-Spark Conditions of Working for the Generator of an Activated Alternating-Current Arc. S. I. Abramson. (Zavodskaya Laboratoriya, 1948, vol. 14, Sept., pp. 1135–1136). [In Russian]. Details are given of a modification of the circuit of an A.C. generator for the production of an improved arc for use in spectroscopic analysis. S. K.

Loss on Ignition of Iron Ores. J. Baron. (Chimie Analytique, 1948, vol. 30, Nov., pp. 250–251). The author discusses the purpose of determining loss on ignition of iron ores and suggests replacing this by the determination of water plus carbon dioxide.—R. F. F.

Spectral Analysis of Iron and Manganese Ores. L. N. Indichenko. (Comptes Rendus (Doklady) de l'Académie des Sciences, U.R.S.S., 1948, vol. 59, pp. 1157–1159 : Chemical Abstracts, 1948, vol. 42, Oct. 10, col. 7112). Distortions of the relative intensities of spectral lines of different elements owing to spattering of the ore in the ordinary carbon arc are avoided by the use of carbon electrodes with a crater up to 3 mm. in dia., 8–10 mm. deep, with 10–12 oblique channels of up to 1 mm. dia. drilled through the walls of the crater ; the lower openings should end near the bottom of the crater, the upper channels at about 3–4 mm. below its rim. The material should be piled into the crater in such a way that the upper channels remain unobstructed. With such electrodes, niobium, zirconium, and nickel lines in magnetite, hematite, and pyrite, and cobalt lines in pyrite, were about two to three times more intense than with the use of ordinary carbon electrodes, and about one and a half to two times more intense than with the method using mixtures of the ore with sodium sulphate.

Quick Method for the Determination of Carbon Dioxide, Calcium Oxide and Magnesium Oxide in Dolomites. N. V. Tananaev. (Zavodskaya Laboratoriya, 1948, vol. 14, Sept., pp. 1131–1132). [In Russian]. The analysis of dolomite by a method which enables the oxides of carbon, calcium, and

magnesium to be determined in 40 min. from a single 0·2-g. sample is described.—S. K.

Determination of Boron in Metals. L. Bertiaux. (Chimie Analytique, 1948, vol. 30, Nov., pp. 252–253). The apparatus, which is similar to Moissan's apparatus, and the method, which is an adaptation of known methods, are described.—R. F. F.

Combined Method for Spectrophotometric Analysis of Gray Iron. G. T. Henderson. (Foundry, 1948, vol. 76, Oct., pp. 93, 224–230). W. B. Sobers has described procedures for determining several elements in cast iron using a solution from a single sample (*see* Journ. I. and S.I., 1944, No. II, p. 65A). In this paper improved procedures are described. R. A. R.

Study of the Estimation of Small Quantities of Chromium in Cast Irons. P. Gaillard and F. Gayte. (Revue de Métallurgie, Mémoires, 1948, vol. 45, Aug., pp. 249–253). Three methods of attacking cast iron samples for the determination of chromium are briefly described and compared. In two, the metal is dissolved in acid, and the chromium and manganese are oxidized by silver nitrate ; in one the permanganate is then destroyed by adding ammonium benzoate and in the other this is effected by means of sodium chloride. In the third method the metal is attacked by perchloric acid followed by hydrofluoric acid ; the chromium is oxidized but not the manganese. In all three methods the chromium is estimated by adding an excess of standardized ferrous ammonium sulphate solution and titrating back with standard permanganate solution. Comparative tests on the three methods are reported. The authors prefer the last method, because the only reagents needed to open up the sample are perchloric acid and a very little hydrofluoric acid, no filtration is required ; there is no need to pour solution from one vessel to another, and the titration is carried out in the original flask.—A. E. C.

Sulphides in Carbon Steel. Iu. T. Lukashevich-Duvanova. (Zavodskaya Laboratoriya, 1948, vol. 14, Sept., pp. 1038–1043). [In Russian]. The separation of sulphides from sulphide-carbide residues is discussed and a method is described which enables the pure sulphides to be obtained in quantities sufficient for microanalysis. Sulphides were obtained in this way from basic and acid open-hearth steels, and from Bessemer and crucible steels, and their chemical compositions and microstructures were investigated. It was found that, in carbon steel, sulphides exist mainly in the form of mutually soluble inclusions of iron and manganese sulphides. Manganese sulphide is less frequently found, while pure iron sulphide is never found in steel containing manganese. The sulphides of iron and manganese were found to be capable of retaining ferrous oxide and silica in their solutions.—S. K.

Polarographic Determination of Copper and Nickel in Steel. A. G. Stromberg, R. V. Dityatkovskaya, and N. V. Milovanova. (Zavodskaya Laboratoriya, 1948, vol. 14, Aug., pp. 919–925). [In Russian]. Polarographic methods were used to study the adsorption of copper and nickel by ferric hydroxide precipitates in relation to the concentrations in the solution of ammonia, ammonium salts, copper, and nickel, as well as to the amount of ferric hydroxide. It was found that such adsorption could be avoided by careful selection of conditions, and on the basis of this a polarographic method is presented for the determination of copper and nickel in steel. Tests carried out under operational conditions proved the reliability, speed, and accuracy of this method for use with numerous samples of steels with copper and nickel contents of 0·09–0·55% and 0·14–9·63%, respectively, the time required for the determination of both these elements in ten samples being 4½ hr.—S. K.

Potentiometric Determination of Manganese in Manganese Ores, Ferromanganese, Nichrome and High-Chromium Steels. A. I. Busev. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1198–1202). [In Russian]. An account is given of experiments on the potentiometric determination of manganese in various materials, and the following conclusions are drawn from the results : The oxidation of bivalent manganese by permanganate in neutral solution to the trivalent state takes place stoichiometrically, and this reaction can be used as the basis for the potentiometric non-compensated method of determining manganese present in ores, ferroalloys, steels (including those high in chromium), and some other products, in concentrations of 0·1% to 90%. No influence on such determinations is exerted by the presence of any amounts of chromium, cobalt, chlorides, molybdenum, tungsten, aluminium, zinc, copper, or other metals.—S. K.

Determination of Magnesium, Molybdenum and Nickel by Polarometric Titration. Z. S. Mukhina. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1194–1198). [In Russian]. Procedures are described for the polarometric determination of magnesium, molybdenum, and nickel which give results sufficiently accurate for umpire analysis. The determination of the first element was used in the analysis of aluminium alloys, the methods for the other two relating to their determination in steels. Molybdenum was separated from iron and chromium, the polarometric titration being carried out after oxidation to molybdate ; solutions of the acetates of lead and sodium were used for titrating and buffering, respectively. It was found essential to remove tungsten and vanadium, and the appropriate modifications of the method are described. For the polarometric titration of nickel, dimethylglyoxime solution was used, Rochelle salt and dextrin being added to the nickel solution. Methods of eliminating the influence of copper and molybdenum in this determination are described. S. K.

Investigation of the Possibility of the Simultaneous Determination of Nickel and Cobalt by the Method of Electrometric Titration. V. G. Sochevanov. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1187–1194). [In Russian]. An account is given of experiments carried out on solutions containing varying amounts of nickel, cobalt, and iron to test the applicability of Chirkov's non-compensated electrometric titration procedure for the simultaneous determination of the first two elements by cyanometric methods. The results show that the method is only reliable for the determination of nickel in the absence of cobalt and iron.—S. K.

Quick Method for the Direct Determination of Ferric Iron by Titration with Mercurous Nitrate. S. A. Babushkin and M. L. Pogrebinskaya. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1182–1186). [In Russian]. The method for the determination of trivalent iron described is based on the quantitative reaction between mercurous nitrate solution and the ferricthiocyanate complex, the disappearance of the red colour indicating the end-point. The strength of the standard mercurous nitrate solution recommended is 0·1 *N*, the results obtained thereby for determination of ferric oxide in open-hearth slags, a manganese ore, dolomite, and some types of brick agreeing well with those obtained by the dichromate method. Details are given for the use of this method for the determination of iron in coal ash, the results obtained being tabulated and shown to agree with those obtained by the usual methods. The presence of hydrochloric acid in concentration $> 1\%$ must be avoided, but sulphuric acid does not affect this method.—S. K.

The Colorimetric Determination of Nickel, Chromium, and Manganese in Steel. H. A. J. Pieters, W. J. Hanssen, and J. J. Geurts. (Analytica Chimica Acta, 1948, vol. 2, Sept., pp. 377–396). The colorimetric determinations of nickel (with dimethylglyoxime), chromium (with diphenylcarbazide), and manganese (after oxidation with periodate) in steel have been critically surveyed with the aid of the Spekker absorptiometer. A recommended procedure is given for each determination. They can be used with steels of a wide range of composition and are accurate within 5%.—R. A. R.

The Determination of Silicon and Manganese in Iron and Steel. (Metallurgia, 1948, vol. 38, Oct., pp. 346–352). This is a report by the Methods of Analysis Committee of the Metallurgy (General) Division of the British Iron and Steel Research Association. Methods of analysis for silicon in plain and alloy steels and irons, excluding those containing major alloying contents of tungsten, or tungsten plus molybdenum, and for manganese in all classes of iron and steel are described. They have been recommended to the British Standards Institution for publication as standards. The silicon method is based on perchloric acid dehydration, and the manganese method on zinc oxide separation of the iron–chromium group and determination by ferrous sulphate and potassium dichromate titration following silver-nitrate/ammonium-persulphate oxidation.—R. A. R.

Photocolorimetric Method of Determining Silicon in Cast Irons and Steels. E. E. Cheburkova. (Zavodskaya Laboratoriya, 1948, vol. 14, Oct., pp. 1261–1262). [In Russian]. Details are given of a photocolorimetric method for the determination of silicon in cast irons, ferromanganese, ferromolybdenum, and various steels containing chromium, tungsten, nickel, and vanadium.—S. K.

Successive Determination of Manganese and Nickel or Chromium and Nickel in Steel from One Sample. A. G. Bogdanchenko. (Zavodskaya Laboratoriya, 1947, vol. 13, pp. 748–751 [in Russian]: Chemical Abstracts, 1948, vol. 42, Oct. 10, col. 7197).

Interference by Cobalt in the Determination of Nickel in Special Steels High in Cobalt and Low in Nickel. F. Gomez Ruimonte. (Anales de Física y Química, 1945, vol. 41, pp. 1457–1462: Chemical Abstracts, 1948, vol. 42, Oct. 10, col. 7197).

The Determination of Copper in Carbon and Low-Alloy Steels. (Metallurgia, 1948, vol. 38, Oct., pp. 342–345). This is a report by the Methods of Analysis Committee of the Metallurgy (General) Division of the British Iron and Steel Research Association. The existing methods of determining copper in low alloy steels are critically examined, and a method is described which has been recommended for publication by the British Standards Institution. The principle involved depends upon a sulphide separation of the copper, ignition, and solution in nitric/sulphuric acids, followed by iodometric titration.—R. A. R.

Spectrum Analysis of Permalloy. A. V. Borsova and N. N. Sorokina. (Zavodskaya Laboratoriya, 1948, vol. 14, Sept., pp. 1098–1100). [In Russian]. A brief account is given of the determination by a spectrum method of nickel, molybdenum, copper, manganese, and silicon in permalloy.—S. K.

Determination of Molybdenum in High-Chromium Steels. E. I. Grenberg and M. O. Ashkinazi. (Zavodskaya Laboratoriya, 1948, vol. 14, Sept., p. 1133). [In Russian]. A colorimetric method for the determination of molybdenum in steels containing up to 13% of chromium is briefly described.—S. K.

The Use of the H.T.A. Gasleak Indicator for Carbon Monoxide. W. J. Klein. (Gas, The Hague, 1948, vol. 68, Apr. 1, pp. 73–75: [Abstract] Chimie et Industrie, 1948, vol. 60, Oct., p. 349.)

The Influence of Foreign Ions on the Colorimetric Determination of Metals. A. K. Babko. (Zavodskaya Laboratoriya, 1948, vol. 14, Sept., pp. 1028–1037). [In Russian]. The ways in which foreign ions can interfere in the colorimetric determination of metals are enumerated, and the methods adopted for avoiding such interference are critically discussed. Particular attention is devoted to the thiocyanate method for the determination of iron.—S. K.

The Photocolorimetric Method of Analysis of Non-Metallic Inclusions in Carbon Steels. N. F. Leve and S. S. Sandomirskaya. (Zavodskaya Laboratoriya, 1948, vol. 14, Sept., pp. 1043–1051). [In Russian]. An account is given of experiments on the colorimetric determination in carbon steel of the following inclusions: Manganese oxide free and combined, ferrous oxide free and combined, manganese sulphide, ferrous sulphide, silica, alumina, and chromic oxide. Both visual and photographic colorimetric methods were used, the results obtained being compared mutually and with those obtained by chemical analysis. The photocolorimetric reactions were chosen so as to enable all the oxide and sulphide compounds present in the inclusions to be determined directly from the fraction obtained in the course of analysis. Inclusions in Armco iron and in several carbon steels were analysed by the photocolorimetric methods found to be most satisfactory: these were: (1) For manganese compounds: the oxide is dissolved from electrolytic residue by ammonium sulphate solution, sulphides being dissolved by subsequent treatment with 1 : 3 sulphuric acid, the manganese in each solution being photocolorimetrically determined using a light green filter after oxidation; (2) for iron compounds: the iron in the various fractions produced in the decomposition of the carbides is determined as the coloured ferrisulphosalicylic complex, special modifications being necessary when the amount of manganese present exceeds 0·05 mg.; (3) for silica: this is determined as the silicate ion forming a yellow coloration with ammonium molybdate solution, the solution before the addition of molybdate being used for obtaining the zero of the photocolorimetric scale; (4) for chromium compounds: the chromium is determined as the diphenyl carbazide complex, pure potassium dichromate solution being used for the calibration; and (5) for aluminium compounds: the reaction of aluminium with cupferron is used, the calibration of the photocolorimetric scale being carried out with solutions of pure aluminium alums; as chromium affects this determination, the zero is obtained with distilled water to which chromate solution has been added to give an appropriate chromium content.—S. K.

First Report of the Gases and Non-Metallics Sub-Committee. Part I—Introduction. W. W. Stevenson. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 388–390). The Gases and Non-Metallics Sub-Committee of the British Iron and Steel Research Association has been formed "to investigate the production of better quality steel from the standpoint of gaseous and non-metallic inclusions; this to include methods of determination and identification of these inclusions and studies of the processes by which they are formed." In this introduction the work is linked to that of the former Oxygen Sub-Committee; the constitution of the new Sub-Committee, and of the Liquid Steel Study Group and Solid Steel Study Group which have been formed, is given.—R. A. R.

First Report of the Gases and Non-Metallics Sub-Committee. Part II—The Determination of Oxygen in Liquid Steel by the Aluminium-Killed Bomb Method. G. E. Speight. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 390–396). An examination has been carried out on bomb samples from acid and basic open-hearth casts with the object of studying the reproducibility of the oxygen result obtained by gravimetric, nephelometric, and vacuum-fusion methods. On specially prepared samples agreement of gravimetric-analysis results was good and that of nephelometric analysis only slightly inferior. Recommendations for the taking and analysis of the bomb sample are appended. The gravimetric method provides an alumina residue which is sufficiently pure in low- and medium-carbon heats to obviate the need for this purification, but in other types of material purification of the original residue may be necessary.

Also included in the report are examples of bomb tests taken from acid heats after deoxidation with ferrosilicon as well as from the ladle, in order to determine whether the method is applicable to deoxidized metal. Agreement between gravimetric and vacuum-fusion tests on the same sample confirms the applicability of the bomb test to deoxidized metal baths. Some interesting results of oxygen determinations on a comparable aluminium-killed and non-killed bomb sample are also included.

First Report of the Gases and Non-Metallics Sub-Committee. Part III—The Determination of Hydrogen in Liquid Steel. G. E. Speight and R. M. Cook. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 397–406). Previous work on the determination of hydrogen in solid and liquid steel and on the development of sampling methods for hydrogen in liquid steel is reviewed. Detailed accounts are given of two methods which have been used in the authors' laboratories. The 'sealed mould' is a closed sampling tube in which account is taken of the hydrogen evolved from the sample during cooling. The 'chilled pencil' is an open tube in which the sample is rapidly cooled. From both types of sample the hydrogen is extracted by vacuum heating at 750° C. The modified extraction apparatus is described in detail. Results are given for low-alloyed open-hearth and electric-arc steels. The hydrogen contents of basic open-hearth casts are, in general, higher than those of basic electric or acid open-hearth casts, average figures being 8 ml./100 g. for basic open-hearth and 6 ml./100 g. for basic electric arc. Brief reference is made to the effects of metal composition on these values.

First Report of the Gases and Non-Metallics Sub-Committee. Part IV—A Co-operative Examination of a Manganese–Molybdenum Steel. T. E. Rooney. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 406–409). Results are presented of micrographic examination and oxygen determinations by vacuum fusion, fractional vacuum fusion, aluminium reduction, and the chlorine and alcoholic iodine residue methods, of a manganese–molybdenum steel. The presence of rhodonite and tephroite and possibly of a small amount of manganese anorthite in an acid-extracted residue is indicated by X-ray examination.

First Report of the Gases and Non-Metallics Sub-Committee. Part V—A Co-operative Examination of a Nickel–Chromium Steel. T. E. Rooney. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 410–412). Results are presented of micrographic examination and oxygen determinations by vacuum fusion, fractional vacuum fusion, aluminium reduction and the chlorine and alcoholic iodine residue methods,

of a nickel–chromium steel. The presence of α-quartz and manganese sulphide in an alcoholic iodine residue and of quartz and a pyroxene of rhodonite type in an acid-extracted residue, was indicated by X-ray examination.

First Report of the Gases and Non-Metallics Sub-Committee. Part VI—A Co-operative Examination of the Distribution of Non-Metallic Inclusions in Billets from a Mild-Steel Ingot. T. E. Rooney. (Journal of The Iron and Steel Institute, 1948, vol. 160, Dec., pp. 413–415). Results are presented of micrographical examinations, X-ray examinations, and oxygen determinations by vacuum fusion and by the chlorine and alcoholic-iodine residue methods. In addition some determinations of nitrogen and hydrogen by the vacuum fusion method are given. Sulphur has also been determined.

The Determination of Gases in Liquid Steel during Smelting. V. T. Braga. (Zavodskaya Laboratoriya, 1948, vol. 14, Sept., pp. 1052–1057). [In Russian]. Three variations of an apparatus for the determination of gases in liquid steel by evacuation are described. Results obtained by two of these methods for the determination of nitrogen, methane, hydrogen, and the oxides of carbon in a liquid steel are compared. Oxygen determinations, made with one apparatus, are compared with those made simultaneously from the same steel by the aluminium method and are stated to be somewhat more reliable. The time required for the determination of oxygen by the method described is 10 min., that for the determination of oxygen, nitrogen, and hydrogen being about 20 min.—S. K.

A Quick Method for the Determination of Sulphur in Coal and Coke. M. M. Bondarenko, S. M. Krolevets, and A. P. Belyaeva. (Zavodskaya Laboratoriya, 1948, vol. 14, Aug., pp. 991–992). [In Russian]. A combustion method for the determination of sulphur in coal and coke is described which requires only 6–8 min. for its execution. In this method 0·1 g. of the material is burnt in a stream of oxygen at 1000–1100° C., the products of combustion being led into starch solution to which standard iodine solution is added from a burette at a rate just sufficient to maintain a blue colour in the liquid. Determinations are carried out previously on samples the sulphur contents of which have been determined by the Eschka, method, the results being used to standardize the iodine solution for use with samples of similar composition. Results obtained by the above method are tabulated and are shown to be accurate.—S. K.

The Moisture Content of Coal and Its Determination. O. Ohlsson. (Fuel, 1948, vol. 27, May–June, pp. 43–45). Three methods of determining the moisture content of coal are described, and it is concluded that none of them is satisfactory for exact determinations. In comparing coal analyses, the method of moisture determination should be specified. R. A. R.

A Consideration of the Volatile-Matter Content of Bituminous Coal on a Dry Ash-Free Basis. J. Hamaker. (Chemisch Weekblad, 1948, vol. 44, Sept. 11, pp. 517–525). [In Dutch]. Experiments on the determination of volatile matter in coal and the effect of the ash content on the determination are reported. By using a liquid with sp. gr. 1·4, a fraction of low ash content was separated off and it was then analysed by a simple method which gave reliable results. It is pointed out that the A.S.T.M. method D388–38 for classifying coal by rank does not take into account the contribution to the volatile matter from the decomposition of mineral matter. R. A. R.

Develop Chemical Methods for Faster Sand Analysis. R. A. Willey and J. B. Caine. (American Foundryman, 1948, vol. 14, July, pp. 50–56). The authors outline suggested procedures for the chemical analysis of foundry sands.—J. C. R.

The Determination of Sodium in Refractory Clay, and Clays Using an Automatic Apparatus. P. D. Korzh. (Zavodskaya Laboratoriya, 1948, vol. 14, Sept., pp. 1088–1091). [In Russian]. Two variations of an automatic method for the determination of sodium in clays are described. Both depend on the jump in the voltage of an electric arc impinging on the sample, which occurs at the instant of the disappearance of the sodium line from the spectrum.—S. K.

MISCELLANEOUS

Some Aspects of the Steel Industry in Australia. E. Lewis. (Bureau of Steel Manufacturers of Australia, 1948, Aug.). After reviewing the sources of coal, iron ore, limestone, and dolomite from which the Australian steel industry obtains its raw materials, the author discusses rolling-mill developments, training of staff, research, incentive payments, and production.—R. A. R.

Preventive Maintenance. E. L. Anderson. (Iron and Steel Engineer, 1948, vol. 25, Sept., pp. 55–56). The author stresses the necessity for close co-operation of management, engineering, operating, and maintenance departments with, when preparing plans and specifications, the periodic inspection of all major equipment, and the proper training and supervision of operators to avoid abuse and damage to equipment.—J. C. R.

Safety in Maintenance and Construction. D. Farrell. (Iron and Steel Engineer, 1948, vol. 25, Sept., pp. 60–61). Safety measures and precautions that can be adopted in works are surveyed.—J. C. R.

New Commercial Tonnage Oxygen System. B. H. Van Dyke. (Steel, 1948, vol. 123, Sept. 20, pp. 103, 104, 134–146). **Flexibility Is Stressed in Design of System for Production of Oxygen.** B. H. Van Dyke. (Blast Furnace and Steel Plant, 1948, vol. 36, Oct., pp. 1212–1215). **Oxygen Generating Systems Has Flexibility.** [Abridged] (Iron Age, 1948, vol. 162, Nov. 25, p. 89). An essential feature of the new "tonnage-oxygen" plant erected by Elliott Co., Jeanette, Pa., is an all-metal gas-to-gas heat-exchanger, the compactness and low cost of which contribute greatly to the economy of the plant. It also facilitates the removal of acetylene, as accumulation might otherwise cause dangerous explosions. The plant has a capacity of 114 tons/day of 95% purity oxygen and 6 tons/day of 99·5% purity oxygen can be simultaneously produced, together with 332 tons/day of 99·5% purity nitrogen. Oxygen recovery from the air is 97%.

BOOK NOTICES

COLOMBIER, L. "*Metallurgie du Fer.*" 8vo, pp. X + 326. Illustrated. Paris, 1948: Dunod (Price 780 francs).

This book is based on a course of lectures prepared mainly for the benefit of operatives in the various branches of the iron and steel industry. The author is head of the research department of the J. Holtzer steelworks, a firm that specializes in the manufacture of high-quality steels. The author's main purpose is to enable the reader to understand the different processes involved in the manufacture of iron and steel, and the functions of alloying elements and heat-treatment. Little space is therefore devoted to details of operations or plant, the emphasis being always on explanations rather than on descriptions or instructions.

So that the explanations may be intelligible to those who have little if any previous knowledge of theoretical metallurgy, and no more than an elementary knowledge of physical chemistry, three introductory chapters are given over to a brief consideration of the relevant fundamental laws of physical chemistry and their application to the study of the reactions involved in the manufacture and heat-treatment of iron and steel.

The next four chapters deal with the large-scale processes (blast-furnace, open-hearth, and Bessemer). Then comes a chapter on "quality," followed by two chapters on the crucible and electric (arc and induction) processes. The next chapter deals briefly with wrought iron and the direct processes, and the next with steel ingots (teeming, solidification, and defects). The remaining four chapters deal very briefly with the manufacture of alloy steels, the function of alloying elements in general and their individual effects, and finally, the various types of normal and special cast irons. Following the main text, there are various supplementary notes elaborating certain interesting points considered by the author to be inessential or rather difficult for the general reader.

There are few references in the text, but it is obvious that the author has read widely and critically. He expresses his own views in a simple and straightforward manner, and as they are based on a wide and up-to-date knowledge of both the practical and theoretical aspects of the subject, the result is excellent.

The lack of an index is rather a handicap, but is partly overcome by the provision of a detailed table of contents.

Naturally, the fact that the book is in French is a much greater handicap. It is written so simply and clearly, however, that the reader need not be a proficient scholar to be able to understand it.—M. S. FISCHER.

F.I.A.T. REVIEW OF GERMAN SCIENCE, 1939–1946. "*Inorganic Chemistry*," Part I. Senior Author, Wilhelm Klemm. 8vo, pp. 278. Berlin, 1948: Office of Military Government for Germany. Field Information Agencies, Technical.

The six-part volume of which this is the first part, should, if the remainder is as thoroughly and carefully carried out, provide a full and useful study of the development of inorganic chemistry in Germany during the war years. The first section alone, dealing with the determination of atomic weight both by chemical means and by the use of the mass spectrograph, indicates that even in war-time conditions a considerable amount of fundamental work was done including the determination of the proportions of various isotopes in such metals as rubidium, thallium, lithium, and silver. The second section reveals that a number of interesting methods were worked out for the extraction of the rarer metals, and many of their atomic, thermal, electrical, and mechanical characteristics were studied. One subsection of this deals with carbon, as graphite, diamond, and the amorphous blacks, the lamellar nature of which is discussed.

The next section deals with nuclear chemistry, and the separation of such radioactive isotopes as those of nitrogen, iodine, and krypton.

The last sections of this part deal at some length with the compounds of metals, semi-metals, and non-metals, and include studies of hydrides, especially of boron which forms chain- and ring-compounds similar in many ways to organic substances, compounds of the halogens among themselves such as chlorine and bromine fluorides, sulphur compounds, where some ring-structures of sulphur and nitrogen are noted, phosphorus compounds of similar structure and, in a field where inorganic and organic chemistries overlap, compounds such as carbonyl cyanide and graphite hydrogen fluoride. Briefer notes are given on the compounds of silicon and the organic derivatives of its acids, while the final paper discusses the compounds of arsenic, antimony and bismuth with phosphorus, and the halogens.—J. P. S.

F.I.A.T. REVIEW OF GERMAN SCIENCE, 1939–1946. "*Geology and Palaeontology.*" Senior Author, Ludwig Rüger. 8vo, pp. 240. Berlin, 1948; Office of Military Government for Germany. Field Information Agencies, Technical.

This work, in the series of reviews of German war-time scientific development compiled by German authors, is divided into three parts, "General Geology," "Formations," and "Palaeontology," and each again into sections which, because of their number, are often brief. Under "General Geology" are first considered the chronology of the earth, with special reference to the light thrown on this by the study of the decay of radioactive substances, and the inner structure of the earth; a long section on dynamic geology follows, considering in particular the tectonics of Middle Europe. The petrography of coal deposits and the geology of oil-bearing strata receive shorter treatment. A final part deals with the study of soils. Interspersed are short papers on the weathering of rocks and on deep-sea sediments. In "Formations" the authors deal with the petrography and stratigraphy, and to some extent the fauna, of the sedimentary formations from the Cambrian to the glacial Alpine deposits. Fuller studies of the fossil contents of rocks are given in "Palaeontology" where, after a preliminary section on micropalaeontology, a range of fossils from sponges to vertebrates, is discussed.—J. P. S.

F.I.A.T. REVIEW OF GERMAN SCIENCE, 1939–1946. "*Physics of Solids,*" Part II. Senior Author Georg Joos. 8vo, pp. 233. Berlin, 1948: Office of Military Government for Germany. Field Information Agencies, Technical.

This is the second of the two volumes of the F.I.A.T. Review devoted to the Physics of Solids. [The first volume was reviewed on p. 238 of the October, 1948, issue.] It deals with magnetic, electrical, and optical properties, and contains a 9-page author index and a 14-page subject index to the two volumes, and lists of the most important journals and new books published during the period under review.

The first article, by W. Klemm and E. Vogt, discusses the magnetic properties of non-ferromagnetic bodies. After a brief account of experimental techniques, the field is divided into six types of non-ferromagnetic behaviour. The influence of the surroundings on the normal diamagnetism of an ion is closely similar to the influence on the molecular refraction. Measurements of paramagnetism have been made on the higher oxides of the alkalis, on ammoniacal solutions of the alkali metals, on neodymium salts in which the ground state of the ion is split by the crystal field, and on liquid or adsorbed oxygen. The temperature-independent paramagnetism of ions of the transition elements has been measured, and forms a basis for predictions of the chemical properties of the trans-uranic elements. One of the most interesting studies has been that of anti-ferromagnetism. Normal ferromagnetism depends on a spin exchange interaction which tends to set the spins of neighbouring ions parallel. In anti-ferromagnetism this interaction has the opposite sign. At high temperatures there is paramagnetism, which increases as the temperature is lowered according to a Curie-Weiss law with a negative Curie temperature $-\theta$. This behaviour does not extend to very low temperatures: at a temperature of about $+\theta$ the susceptibility reaches a maximum, and falls towards zero at zero temperature. The theory cannot be based on the simple Weiss approximation of an internal field proportional to the mean polarization, for in the state of anti-ferromagnetic saturation the orientating force on each ionic spin is strong, while the mean polarization vanishes. Instead, the theory is modelled on the theory of short-range order in alloys. The anti-ferromagnetic spin interaction corresponds to homopolar binding in compounds such as VO_2 and FeS. The dependence of the exchange integral on the distance between neighbouring magnetic ions and on the size of the specimen, and the crystal chemistry of compounds of the transition elements, have been investigated in detail. Anomalous (large) diamagnetism has been studied in graphite and its derivatives, cyclic carbon compounds, and γ-alloys. There are new systematic measurements of the magnetism of the elements, of alloys, of organo-metallic and hydrated ions, and of organic free radicals.

A very clear article by R. Becker on ferromagnetism begins with a discussion of the Heisenberg theory of ferromagnetism, and shows how apparent anomalies in the dependence of magnetization on temperature and pressure have been explained. It is then pointed out that the size of the Weiss domains is usually determined by the imperfections of the specimen, and not by the theoretical balance between the energies of domain walls and of the demagnetizing fields. Measurements of the magnetic properties of thin films (25 Å) of iron are reported. Turning to a discussion of the technical magnetization curve, Becker outlines the theories given in the book published by Döring and himself just before the war, and related experimental studies of the approach to saturation, the remanence of magnetostriction, the effect of external stress on the initial permeability, and, conversely, the effect of a strong magnetic field on the elastic modulus ΔE-effect). Related to the latter is a damping of mechanical vibrations by inverse magnetostriction, which is proportional to the Rayleigh loss in a small hysteresis cycle. Experiments have also shown unexplained departures from the Rayleigh formula for the magnetization in weak fields. Two theories of the coercive force are given. The first, due to Kondorski and Kersten, attributes the coercivity to variations in the energy of the Bloch wall between domains as it moves from place to place in the strained lattice. These variations are caused by inverse magnetostriction. The theory gives a relation between initial susceptibility and coercivity, and predicts the magnetic field which gives the maximum permeability of a deformed nickel wire. The second theory, published by Kersten as a monograph in 1943, applies to materials such as iron which contains highly dispersed carbide or nitride particles, but which has been annealed to remove internal strains. The variation in wall energy is now ascribed to the low or zero saturation moment of the included particles. A formula is derived which contains no arbitrary constants, and gives satisfactory estimates of the coercive force of such materials, and the initial permeability of recrystallized carbon steels is discussed. Becker suggests an extension

of the theory to allow for the large energy of the demagnetizing field of a non-magnetic inclusion. The magnetic properties of recrystallized rolled sheet are analysed, but not explained. There have been several investigations of the effect of mechanical vibrations on the hysteresis loop. The hysteresis loop for large fields is made narrower by vibration, but in weak fields the hysteresis is increased.

There follow chapters by C. Schmelzer on dielectrics and by E. Gerber on piezoelectricity. Three chapters by W. A. v. Meyern deal with the conduction of electricity in insulators and in semi-conductors.

A short article by G. Hettner deals with the conduction of electricity in metals. It is largely concerned with refinements of the electron theory, and with experimental and theoretical work on the influence of magnetic fields on the electrical conductivity. Experimental methods are described for resistance measurements at very high and very low temperatures, and there is a bibliography of resistance measurements on metals and alloys. Resistance measurements on sputtered and evaporated thin films are reported. The section by J. Meixner on galvanomagnetic, thermomagnetic, and thermoelectric effects is mostly theoretical and is of considerable importance. It has two main themes, which draw support from one another. The first is Meixner's own theory of the thermodynamics of irreversible processes. Suppose, for example, we are concerned with the Thomson effect, the "specific heat of electricity." We set up a temperature gradient in a wire, and observe the increase in heat flow down the wire when a current is passed. If the current is very small, this thermodynamically reversible flow of heat is small in comparison with the irreversible conduction of heat on which it is superimposed, and a clear thermodynamic treatment of the reversible flow is not possible. If the current is increased to meet the objection, the irreversible Joule heat increases as the square of the current, and ultimately becomes greater than the Thomson heat. Thus the ratio of reversible to irreversible heat has a minimum which cannot be reduced, and thermodynamics lead, not to Thomson's second equation between Peltier effect and thermoelectric effect, but to a less precise inequality. To obtain the equality, it is necessary to appeal to Onsager's reciprocal relations, which are not deducible from formal thermodynamics. The second theoretical theme is a detailed study of all these effects in terms of the electron theory of metals by Kohler. Experimental investigations of the effect of a magnetic field by Justi and others, and measurements on semi-conductors, are reported.

W. Meissner and G. O. Schubert describe new superconductors, including NbN, which remains superconducting up to 23° K., and retains traces of superconductivity up to 112° K. These compounds show a large temperature hysteresis. The transition state between normal and superconductivity has been studied in detail, as has the current distribution in multiply connected superconductors. A detailed summary is given of v. Laue's complete phenomenological theory of superconductors, which is based on the theories of F. London and Gorter. There have been two attempts to base the theory of superconductivity on the electron theory of metals. The first, due to Welker, admits that the direct magnetic interaction between the paths of two electrons leads to a state of lowest energy when these are anti-parallel, so that the total current vanishes. However, there must be a magnetic exchange energy which favours the state in which the two paths are parallel, so that the total current does not vanish. Welker estimates that below 1° K. this magnetic exchange energy may be larger than the classical magnetic interaction. The other theory, due to Heisenberg, attributes the superconductivity to the Coulomb repulsion between the few electrons on the surface of the Fermi energy distribution which are free to contribute to the conduction. Because of this repulsion, they form a 'superlattice' in the material, and this lattice travels through the material with the speed corresponding to the top of the Fermi distribution, producing a current which cannot be destroyed without breaking up the lattice. One of the strongest arguments for the theory is that it predicts that a high effective mass of the electrons and a small velocity will raise the critical temperature, which is in agreement with the observed high transition temperatures of some semi-conductors.

The senior author, G. Joos, contributes a chapter on the optical properties of solids, including a section on the reflectivity of oxide-free aluminium and the optical constants of thin (20 mμ) films of platinum and rhodium. The final chapter by W. Hanle and A. Schmillen, treats with phosphorescence, luminescence, and thermal radiation.

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